Engineering Report of the AirCell Compatibility Test

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1 Executive Summary

AirCell developed a system that utilizes modified terrestrial analog (AMPS) cellular mobile units, transmitting on “standard” cellular frequencies to accomplish air-to-ground cellular telephony calls. The basic premise of the AirCell System assumes low power airborne units transmitting at large distances from potentially affected terrestrial cellular sites will go unnoticed by existing terrestrial cellular subscribers, as the resulting received airborne signals are considered to be at or below ”noise floor” levels of contemporary terrestrial cellular systems. AirCell performed limited flight tests and developed a statistical analysis that helps form their conclusion that any potential interference that is generated is not significant and therefore not harmful to terrestrial cellular networks and subscribers. Further, AirCell claimed that any potential interference caused by their airborne subscribers would be detected with conventional terrestrial switch based statistics tools, and thereby addressed.

The FCC, in a Memorandum Opinion and Order (MO&O) specifically addressing a waiver allowing operation of the AirCell System as a secondary service of cellular frequencies, defined “harmful interference” as “serious obstructions, degradations, or repeated interruptions of cellular service,” utilizing the standard definition. In a subsequent order, however, the FCC took the position that to be “harmful,” interference would have to exceed “objectionable interference resulting in noisy calls that would be annoying to [the] caller.”

Concerned about the potential impact to tens of millions of terrestrial cellular subscribers, a consortium of cellular operators, including Verizon Wireless, Cingular Wireless and AT&T Wireless, retained V-COMM, L.L.C. as an independent engineering consulting firm to study the compatibility of the AirCell system with analog and digital cellular service. V-COMM developed a comprehensive test plan referred to as the “AirCell Compatibility Test Plan” and attached herein, which would assist in determining any compatibility issues with AirCell’s air-to-ground secondary use of cellular frequencies relative to terrestrial cellular operators’ primary use of this same spectrum. Under its test plan, V-COMM performed a series of controlled tests designed to directly measure the impact of potential AirCell interference. A significant amount of data was collected and processed in order to develop “empirical” insight as compared to AirCell’s “statistical” insight. These tests were performed in the northeastern portion of the United States, a region with a high concentration of population, aircraft and corresponding air traffic, as well as significant terrestrial cellular subscriber penetration and network deployment. Further, additional tests were developed and executed which would measure the actual noise floor in the test area. Finally, a Case Study was developed utilizing the results from the controlled tests, correlated to typical flight data and patterns, to determine a likely daily and repetitive scenario under which both networks would simultaneously operate.

V-COMM’s findings, based upon the aforementioned tests, confirm the following:

1. Airborne AirCell signals received by terrestrial cellular sites were measured as high as -72 dBm, and frequently in the -90 dBm to -100 dBm range.
2. The median operating noise floor (as measured) on actual terrestrial cell sites within the test area was between -123 dBm and -127 dBm, for four market types.
3. "Toll quality" terrestrial cellular calls on cell sites within the test area can be maintained at received signal levels as low as -110 dBm.
4. Airborne AirCell signals received by terrestrial cell sites, at levels measured during the various tests within the "AirCell Compatibility Test Plan", have the potential to cause significant harmful interference, which is exhibited as:
    a. Degraded call quality (i.e. degraded Mean Opinion Score (MOS))
    b. Dropped calls
    c. Blocked calls
    d. Reduced system capacity

    All or some of these characteristics are exhibited on each technology tested, AMPS, TDMA and CDMA.
5. Harmful interference to terrestrial cellular service is observed, in tests with injected interfering signals as low as -123 dBm for AMPS, and -120 dBm for CDMA and TDMA.
6. The Case Study demonstrates the magnitude of terrestrial sites affected on typical flights within the test area. In particular, the horizontal and Slant 45 polar terrestrial antennas, exhibited the highest received signal levels and affected terrestrial sites. As many as 1500 and as few as 200 sites would be affected from airborne calls being made on a typical 40 minute flight between Washington, D.C. and the New York metro area. The magnitude of individual terrestrial cellular calls affected by one AirCell call along this typical flight route is as low as 200 and as high as 30,000, thereby producing a ratio ranging from 1:200 to 1:30,000 to describe the impact of the secondary user on the primary users of this cellular spectrum.
7. Terrestrial cellular sites and subscribers in rural areas are expected to receive the greatest impact from airborne interference on a per call basis. However, terrestrial sites and subscribers in densely populated areas are expected to be significantly impacted as well, due to high subscriber usage within buildings, which results in received signal strengths close to those received in rural areas.
8. The tests performed and results collected pertain to technologies that are currently widely deployed (i.e., AMPS, TDMA and CDMA). Additional tests would be required to determine actual impact to future and newer technologies such as 3G (voice and data), E911 Location technologies, etc. Initially, it is anticipated that the impact to these future and newer technologies would be greater than current technologies due the utilization of lower operating power levels and higher modulation levels of these technologies.

In conclusion, the AirCell air-to-ground system was originally designed to minimize interference to terrestrial cellular systems. AirCell claims, based on limited tests and

small data samples reviewed by statistical analysis, that received interference to terrestrial cellular systems is miniscule and statistically insignificant. Conversely, V-COMM has conducted tests that indicate airborne received signals can be great enough to cause harmful interference to terrestrial cellular subscribers. Further, V-COMM has developed a Case Study which demonstrates that this harmful interference can be generated and repeated in a typical daily scenario, and not just an isolated case. V-COMM has also conducted tests on typical terrestrial cell sites, which indicate that noise levels on these sites are sufficiently low that interference from airborne AirCell units will compete with regularly received terrestrial signals at normal, acceptable quality levels. Therefore, we conclude that despite AirCell's system design efforts to minimize interference to terrestrial cellular systems, the actual airborne signals generated from the AirCell air-to-ground cellular telephony system cause harmful interference to terrestrial cellular systems.

2 Introduction & Overview

This report has been prepared by V-COMM, L.L.C., a full service engineering and consulting firm fulfilling the needs of the wireless telecommunications industry since 1996. Biographies of key individuals contributing to the report and associated testing as well as an overall profile of V-COMM, L.L.C., are included in Appendix section 9.1 of this document.

This report documents the findings of tests performed under Phase 1 and Phase 2 of the "AirCell Compatibility Test Plan" as developed and executed by V-COMM. A copy of the "AirCell Compatibility Test Plan" is included in the Appendix (Section 9.18) to this document.

In addition, the report presents a case study designed to reflect the compatibility issues that are expected when operating AirCell equipment on a typical flight within the northeast corridor. The case study takes into consideration existing cell sites along the flight path. Actual flight and aircraft data were used to model a typical flight route, all of which are included in section 6 of this document. The case study uses the results from the Phase 1 flight tests and Phase 2 interference tests in the analysis.

The Conclusion section of this document summarizes the findings from the Phase 1 and Phase 2 tests. This summary of findings includes the relationship between the Phase 1 and Phase 2 collected test data and the case study performed. Finally, the report includes an Appendix section containing support information and additional results of the Phase 1 and Phase 2 tests.

2.1 Purpose of Test

The purpose of the tests conducted under the "AirCell Compatibility Test Plan" was to develop an understanding of the operation of the AirCell air-to-ground system and its compatibility with existing terrestrial digital and analog cellular systems.

2.2 Introduction of the "AirCell Compatibility Test Plan"

As previously mentioned, the "AirCell Compatibility Test Plan" was developed and executed by V-COMM, L.L.C. V-COMM's role was to serve as an independent expert engineering firm in the development and execution of these tests. The tests were performed within the northeastern portion of the United States, specifically within the New York, New Jersey and Philadelphia, Pennsylvania markets. The cellular operating companies in this region provided the necessary cell site access as well as operational network performance data. Both the A and B band cellular operators in this region have deployed Lucent infrastructure for their cellular networks. The testing was also

observed by Lucent Technologies, in order to provide additional expertise and network insight with respect to cell site equipment and performance metrics.

The “AirCell Compatibility Test Plan” document is provided in Appendix Section 9.18, which includes a detailed description of the test procedures and methods used in these tests.

2.2.1 Phase 1 and 2 of the AirCell Compatibility Test Plan

The “AirCell Compatibility Test Plan” involved two phases of testing, with several different scenarios. All tests under this plan are considered “controlled” tests. The reasons for conducting controlled tests to study the compatibility of the AirCell system are provided in section 2.2.4. The benefits of this testing allow for reliable, accurate and re-producible results. With these measurements, detailed analyses and case studies can be used to accurately predict the outcome of situations of both negligible and significant concern.

Each phase of testing served a different purpose and was applicable for different scenarios. The purpose and scenarios are outlined briefly below, and in great detail in the AirCell Compatibility Test Plan, provided in Appendix Section 9.18.

2.2.2 Phase 1 Flight Tests

In Phase 1, as described in the “AirCell Compatibility Test Plan”, flight tests were performed with the AirCell mobile phone Dynamic Power Control (DPC) algorithm functioning normally, and in other tests with the AirCell mobile phone at its fixed maximum power (with DPC disabled), for the reasons provided below.

All flight tests were performed with the AirCell airborne mobile served by the Marlboro AirCell site, and within the NJ, NY & Philadelphia airspace.

<u>Phase 1 Flight Tests, with AirCell DPC Enabled</u>

In flight tests performed under Phase 1A tests pursuant to the “AirCell Compatibility Test Plan”, the AirCell DPC parameter was enabled and operating in its normal mode, as optimized by AirCell. In these tests, the flight patterns were typical flight routes within the NJ, NY & Philadelphia airspace. A variety of flight patterns, altitudes, aircraft types and distances from the serving AirCell cell sites were measured and recorded in order to develop a data set of typical operating AirCell DPC and power levels of the AirCell air-to-ground system during these flight tests. The results of these flight tests, with DPC enabled, are used in additional analyses to determine the power level of the AirCell mobile at various altitudes and distances from its serving AirCell cell site.

Phase 1 Flight Tests, at Fixed Maximum Power (AirCell DPC Level 2)

In flight tests performed under Phase 1B tests pursuant to the "AirCell Compatibility Test Plan", the AirCell mobile DPC power level was fixed to its maximum level (DPC Level 2), which corresponds to the 75 mwatt FCC limit. All other AirCell system parameters were operating normal. In these tests, a variety of flight patterns, altitudes, aircraft types and distances from the terrestrial cell sites were measured and recorded in order to develop a data set of the received signal levels at the terrestrial cell sites. The results of these tests, with DPC disabled, are used in additional analyses to determine the range of AirCell signal levels received at the terrestrial site, with the AirCell airborne mobile at various altitudes and distances from the terrestrial cell site. This data can be used in a variety of analyses, including the case study provided in section 6 of this report, which models a typical flight path. With this measured data set, modeling of specific situations can be accurately performed by offsetting the maximum AirCell mobile power results by the appropriate 4 dB decrement (DPC attenuation step[1]) to match the application.

In cases when the AirCell mobile *is* transmitting at maximum power, these test results represent the compatibility issues under that circumstance, with no offset required.[2,3] This case is significant and needs to be studied to ensure that harmful interference will not occur when the AirCell system is at its maximum power. If harmful interference occurs with AirCell airborne mobile units at their maximum power, it can be concluded that the FCC limits are not sufficient to protect terrestrial cellular service.

Because the AirCell DPC function is independent of the distance to the victim terrestrial cell site, it is more appropriate to conduct tests and study the AirCell system compatibility variables (path loss to terrestrial system & AirCell power level) in separate flight tests. The benefits of conducting separate tests allow the results to be more

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[1] The AirCell DPC algorithm adjusts the mobile unit transmitting output power as a function of RSSI (received signal strength) from the serving AirCell site. The range of this variable is DPC=2 through 7, each step being a 4 dB decrement, with step 7 being lowest transmitting power.

[2] The AirCell mobile DPC function has the potential to operate at DPC level 2, 3, 4, 5, 6 or 7, which represents a total of 6 power steps. With a proportionate distribution of power levels, the AirCell mobile will be at maximum power (DPC=2) approximately 1/6 of the time. In addition, when the AirCell mobile is flying further away from its serving site, closer to neighbor terrestrial cellular markets, there is an even greater likelihood that the AirCell mobile is transmitting at its maximum power level (ie. greater than 1/6 of the time). Studying the AirCell system compatibility issues, with AirCell mobiles at maximum power, is useful in this situation.

[3] AirCell cell sites utilize control channels that are not controlled by the DPC feature, and mobiles transmitting on reverse control channels will be at maximum power all the time. The potential interference from AirCell control channels to the terrestrial system is observed in test results with DPC disabled, with no adjustment to the received signal levels. The AMPS control channels are used in setting up new calls and auto-registration of all mobiles within the coverage area of each base station at periodic intervals.

accurate and reliable, and it allows better understanding of the results. In these tests, the AirCell signal received by the victim terrestrial site from airplanes with different orientations to the victim terrestrial cell site can be measured without power fluctuations affecting the results. This allows us to measure and analyze the impact of airplane orientation (altitude, distance, and angle from terrestrial site) with respect to the maximum range of possible signal levels received at the terrestrial site.

In addition, since AirCell sites may be optimized using different system DPC parameter settings[4] and utilize other equipment (i.e. Smart Antennas), it is beneficial to study the AirCell system at its fixed maximum power level. With these results, a data set of signal path loss measurements can be developed that are representative of the AirCell system. Then, in subsequent tests, the AirCell mobile transmit power levels can be measured, for each application that exists in AirCell's operation. With these results, the compatibility of the AirCell system can be studied without conducting significantly more tests, since the path loss measurements need not be re-tested, as they will not change regardless of the AirCell system parameters and equipment used at the AirCell site. For these reasons, the AirCell DPC power levels are measured in separate flight tests, as described in the Phase 1A tests above.

2.2.3 Phase 2 Interference Tests

In Phase 2, pursuant to the "AirCell Compatibility Test Plan," tests were performed with simulated AirCell signal levels injected into the receive path of representative terrestrial cell sites. In these tests, the cellular system performance metrics were monitored and recorded to determine whether harmful interference is occurring. These tests were performed within the coverage area of the suburban terrestrial test cell site, and with the cell site operating under normal day-time market conditions. By performing these tests for each technology (AMPS, TDMA & CDMA) used by the cellular network operators in this area, analyses can be performed to determine the impact of potentially interfering AirCell mobile signals on the terrestrial cellular networks.

In addition, the cell site operating noise floor of the terrestrial suburban test cell site, and 18 others in the surrounding area, were measured and are provided in this report.

2.2.4 Reasons for Conducting Controlled Tests

The purpose of tests under Phases 1 and 2 of the "AirCell Compatibility Test Plan" is to collect reliable data that could be used to accurately predict a variety of situations in which an AirCell airborne mobile unit had the potential to cause harmful interference to

[4] Provided in section 7.6 of this report is an explanation of the AirCell DPC parameters and optimization levels used at AirCell sites. Since the parameter settings vary from site to site, other AirCell sites may have different results.

terrestrial cellular systems. Once accurately modeled, all interested parties would be able to determine if the potential for harmful interference was negligible or significant.

In previous statements, AirCell has suggested that switch based interference detection tools could be utilized to ascertain the potential for harmful interference caused by airborne AirCell units to terrestrial cellular systems. However, when used outside the confines of a controlled test, these tools do not provide conclusive, measurable, or reliable results. A controlled test is the only method of measurement that will yield conclusive and reliable results. This is explained in greater detail in Appendix 9.2.

3 Results of Phase 1 Tests

3.1 Introduction

Phase 1 flight testing was performed to establish a variety of airborne AirCell signal levels that could be received by terrestrial cell sites in the presence of an AirCell equipped airplane on an AirCell telephone call. To perform these tests, AirCell equipped airplanes were utilized and flown at different altitudes and flight patterns in the coverage area of the AirCell Marlboro, NJ site. While these flights were taking place, equipment at three terrestrial cell sites were configured to collect and record the received AirCell signal strength throughout the test. The Phase 1 flight tests utilize four different types of terrestrial antennas for measurements, two different types of AirCell airborne mobile antennas, various flight plans and test scenarios described below. Refer to the AirCell Compatibility Test Plan document, provided in Appendix Section 9.18, for a more detailed description of the test plan and test procedures.

In Phase 1 tests, a series of aircraft flight tests were conducted over several months time, from November, 2000 to July, 2001. These flight tests were coordinated with regional FAA and air traffic control centers. A comprehensive and significant number of flight tests were performed in Phase 1 tests. A total of over 10,000 air miles are included in the Phase 1 flight tests, which represent over 50 hours of flight testing.

3.1.1 Aircraft Equipment, Flight Plans & Test Scenarios

In Phase 1 flight tests, different aircraft were used for low and high altitude flight tests. These aircraft were chosen to represent typical aircraft with AirCell installations, and typical aircraft flying at the altitudes specified in the test plan. For high altitude tests, a jet engine type aircraft with AirCell's belly-mounted antenna was utilized. For lower altitude tests, a twin engine piston type aircraft with AirCell's VOR antenna was utilized. Pictures of these aircraft and AirCell mobile antennas are provided in the AirCell Compatibility Test Plan. For a median flight altitude (10,000 ft), both aircraft were used for comparison. All aircraft were equipped with standard operating AirCell equipment, and were installed by an AirCell authorized installation facility. All aircraft use the appropriate AirCell antenna designed for their respective airplane type, as specified and configured by AirCell.

The aircraft flight plans utilized in the tests were designed to capture significantly more flight data than previous tests. These flight tests were performed in an effort to model the compatibility of the AirCell service with terrestrial cellular service. Many flights were included to capture typical orientations of aircraft to the victim terrestrial cell site & serving AirCell cell site. All flight plans were within the coverage area of the Marlboro, NJ AirCell cell site. The flights include altitudes from 2,000 feet to 35,000 feet above

mean sea level, and at distances up to 135 miles away from the AirCell Marlboro cell site.

Phase 1 flight tests were performed with the AirCell mobile Dynamic Power Control (DPC) feature either enabled or disabled, in order to accurately study the "real world" impact of AirCell operations. The reasons for conducting these flight tests in separate tests are provided below.

In flight tests with DPC disabled, the AirCell mobile unit transmits at its maximum power level (DPC level 2), which is approximately 75 milliwatts, or the maximum level permitted by current FCC Waiver limitations. Testing with DPC disabled allows the path loss (AirCell airborne mobile to the victim terrestrial cell site) to be measured with precision in order to produce a "data set" of received signal levels. With this data set, a variety of analyses can be performed to evaluate compatibility of the AirCell system, and accurately model case studies of typical flights. With this data set, additional analyses can be performed with the effects of DPC included (as measured in separate flight tests) by offsetting the signal strength received at the terrestrial cell site with the appropriate 4 dB decrement (DPC attenuation step[5]) to match the application. Four different types of terrestrial receive antennas are used in these tests, with three different antenna polarities for comparison (horizontal, slant 45 degree, and vertical polarity).

In flight tests with DPC enabled, the parameter settings for the airborne mobile unit and AirCell Marlboro cell site are configured and optimized by AirCell.[6] With these settings at Marlboro, the airborne mobile unit will not reach its maximum power level of 75 mwatts (allowed under FCC waiver limits), which is the AirCell DPC level 2. AirCell configured the Marlboro site to a maximum power level of DPC=3, which is approximately 30 mwatts. This is the maximum transmit power level that airborne mobile units achieved in the Phase 1 flight tests with DPC enabled. In these flight tests, a data set of the AirCell mobile DPC power levels can be measured for various flight patterns, altitudes and distances from its serving AirCell Marlboro cell site. With these results, additional analyses can be performed, which include modeling other flight paths and determining the effects of altitude and distance from its serving cell site, has with respect to the AirCell mobile DPC power level. In addition, the results of these tests include the maximum range of the AirCell site, as configured by AirCell, and also the minimum range to reach maximum power.

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[5] The AirCell DPC algorithm adjusts the mobile unit transmitting output power as a function of RSSI (received signal strength) at the serving AirCell site. The range of this variable is DPC=2 through 7, each step being a 4 dB decrement, with step 7 being lowest transmitting power.

[6] AirCell optimizes its sites on a case by case basis, with different operating parameters for each site. At some sites, the power of the mobile is capped one or two DPC steps below the maximum power (75 mwatts) allowed under the FCC waiver — i.e., at DPC Level 3 or 4 — while at other sites, AirCell uses 75 mwatt maximum power setting for the mobile, corresponding to AirCell DPC Level 2. See Section 7.6 for more information on the AirCell Cell Site Parameters and Optimization.

The flight tests with DPC enabled utilize typical “straight-line” flight patterns. The flight tests with DPC disabled utilize circular flight patterns, around the terrestrial Marlboro cell site, to measure signals from all directions as received by the terrestrial antennas. The flight patterns used in Phase 1 tests are depicted in Figure 9.3-A and Figure 9.3-B, in the Appendix Section 9.3. For a more detailed description of the flight patterns used in the Phase 1 tests, refer to the AirCell Compatibility Test Plan, provided in section 9.18.

The AirCell DPC function is based on the mobile signal level received at the AirCell base station and is therefore independent of the distance to the victim terrestrial cell site. It is therefore more appropriate to conduct tests and study the AirCell system compatibility variables (path loss to terrestrial system & AirCell power level) in separate flight tests, as described above. Conducting separate tests allows the results to be more accurate and reliable and allows better understanding of the results. In these tests, the AirCell signal received by the victim terrestrial site from airplanes with different orientations to the site can be measured without power fluctuations affecting the results. This allows us to measure and analyze the impact of airplane orientation (altitude, distance, and angle from terrestrial site) with respect to the maximum range of possible signal levels received at the terrestrial site. These results can then be adjusted to reflect the effects of DPC, as measured in the DPC-enabled tests, and the combined results of these two test scenarios (DPC enabled and disabled) allows modeling of the effects of received airborne signals in various situations.

3.1.2 Terrestrial Cell Sites

In Phase 1 flight tests, receiver test equipment was located at three terrestrial cell sites to measure the received AirCell signal strengths. Four types of terrestrial cell site antennas were used, which are representative of the types of antennas that are commonly deployed in cellular networks today. These include horizontal polarization, vertical polarization, and Slant 45 degree cross-polarization. Three separate terrestrial cell sites were used for the collection of data as described below.

<u>Marlboro, NJ Terrestrial Cell Site</u>

Four terrestrial cellular test antenna types were mounted on the cell site tower at an antenna center-line of approximately 140 feet above ground level, as indicated in the AirCell Compatibility Test Plan, attached in the Appendix Section 9.18. Coaxial cable transmission lines (1 ¼ inch in diameter) were connected from the four terrestrial test antennas to Grayson test receivers located inside the base station equipment building. The four terrestrial test antennas used the Phase 1 flight testing are the following:

- OMNI – Vertically polarized Omni-directional antenna, Decibel Products DB589
- V-POL – Vertically polarized panel antenna, Decibel Products DB844H90
- H-POL – Horizontally polarized panel antenna, Decibel Products DB854HV90
- SL45 – Slant-45 degree cross-polarized panel antenna, EMS RR90-12

These antennas represent typical terrestrial cellular antennas in use by cellular operators in the United States. These specific models, or electrically equivalent versions manufactured by other antenna vendors, with antenna gain of 9-12 dBd, make up a cross section of what is deployed across the United States.

Since these four terrestrial antennas are collocated at the same cell site location and elevation on the tower, their received signal strengths are directly comparable. These four terrestrial antennas are mounted on a tower platform, on the west side of the tower, and the panel antennas azimuths are oriented 270 degrees from true north (ie. pointing west). With these antenna azimuths, as can be expected, the highest AirCell airborne signals are received at the panel terrestrial antennas when the aircraft is flying within the airspace west of the Marlboro terrestrial antennas (see Figure 9.4-A to Figure 9.4-C in Section 9.4). Also, as can be expected, the highest AirCell signals are received at the panel antennas with more gain and on the dual-polarity terrestrial antennas (H-POL and SL45).

The vertically polarized, panel-type sector antenna is the most common type of antenna in terrestrial cellular networks today.[7] However, the dual polarity diversity antennas, Horizontal/Vertical and Slant 45 degree antennas, are becoming increasingly popular in rural, suburban, urban and dense urban markets due to increased difficulties with cell site zoning, construction and site acquisition issues. Many cellular operators plan to install the dual polarity type antennas to meet the market demands and the growth of their cellular networks. For example, Cingular Wireless plans to install approximately 45,000 dual polarity type antennas over the next two-year period, throughout their nationwide cellular network.[8] This trend is expected to continue into the foreseeable future.

<u>Oak Hill Terrestrial Cell Site (King of Prussia, PA) &</u>
<u>Swainton, NJ Terrestrial Cell Site</u>

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[7] The vertically polarized panel antenna is the most common terrestrial antenna in all markets types. In rural markets, the panel antenna is more common today and offers increased antenna gain with improved coverage and capacity over the omni-directional antenna.

[8] Cingular Wireless plans to install approximately 45,000 dual polarity antennas, as approved in an FCC order (DA 02-558 issued on Mar. 7, 2002), in response to Cingular Wireless' Petition for Waiver of Section 22.367 of the Rules Concerning Wave Polarization in the Cellular Radiotelephone Service (filed Nov. 20, 2001). Cingular Wireless states that because dual-polarized antennas do not have to be "physically spaced apart" a polarization diversity antenna array can be packaged in a single compact radome, reducing the number of antenna modules required at a given terrestrial cell site. Cingular Wireless states that the use of dual-polarized antennas will serve the public interest by reducing the visual impact of the towers, reducing tower loading, minimizing the need for new tower construction, and minimizing zoning issues. Cingular needed a waiver because Section 22.367 barred analog systems' use of non-vertically polarized transmit antennas. Without a waiver, horizontal and cross-polarized antennas could only be used as receive antennas in analog systems (there was no restriction on polarization in digital systems). The restriction was eliminated in the FCC's Part 22 Year 2000 Biennial Review Report and Order (FCC 02-229 issued on Sept. 24, 2002).

Two other terrestrial cell sites were utilized in the Phase 1 testing, which are the Oak Hill and Swainton terrestrial cell sites. At these two sites, the terrestrial antenna utilized in the testing is the same that is used by the cellular operator at those sites. These terrestrial antennas are the “standard” vertically polarized panel antennas, with similar specifications to the vertically polarized panel test antenna used at the Marlboro site (V-POL).

The Grayson test receivers at these terrestrial cell sites were connected directly to the installed cellular base site equipment utilizing the splitter within the antenna interface frame of the cell site, as specified in the AirCell Compatibility Test Plan (Appendix, Section 9.18).

The signal path offset from the input of the terrestrial cell site (hatch plate reference) to test receiver was measured for the three terrestrial cell sites used in Phase 1 flight tests. The reference point for all signal levels provided in this report is the input of the cell site (hatch plate reference).

3.2 Phase 1 Test Results – AirCell Signals Received at Terrestrial Cell Sites

The Phase 1 test results provided in this section were completed with the AirCell airborne mobile power at its maximum power level, which is 75 mwatts as permitted under current FCC waiver limitations, correponding to AirCell DPC level 2. In the flight tests, the serving AirCell cell site is the Marlboro, NJ cell site. During these tests, the AirCell mobile DPC feature was disabled, as specified in the AirCell Compatibility Test Plan in Appendix Section 9.18. The purpose of disabling the DPC feature was to collect received signal strength data representing the path loss of the AirCell airborne mobile to the terrestrial site, without power fluctuations affecting the results. With these results, the received signal levels and corresponding distances to the victim terrestrial cell site can be observed. And in other flight tests, with DPC enabled (in Section 3.3), the AirCell mobile DPC levels and corresponding distances to the serving AirCell cell site can be observed. The results of both of these tests are used in additional analyses to determine the potential effects to thousands of terrestrial cell sites along a typical flight plan, as provided in the case study section 6.

Testing with the AirCell mobile transmit power at its maximum level (AirCell DPC level 2) provides better understanding and analysis of the compatibility issues associated with the AirCell system. In these tests, the distribution of received signal levels at the terrestrial cell sites can be observed, as a function of the aircraft altitude and distance from the victim terrestrial cell site. The results of these tests are provided in graphs at the end of this section, and in the appendix at Sections 9.4 and 9.5. The flight patterns used in these flight tests are provided in the appendix at Section 9.3.

During these flight tests, measurements are collected at 3 terrestrial cell sites. At the Marlboro cell site, the H-POL, SL45, V-POL and OMNI terrestrial test antennas are used. The results from these four antennas can be directly compared, since the antennas are collocated and have the same orientation to the aircraft. Additional measurements are provided from the terrestrial cell sites Oak Hill and Swainton (using similar panel antennas as the V-POL), with antenna azimuths pointing toward and away from the flight patterns, as described in the test plan.

Observations from the Phase 1 Test Results, with the AirCell mobile transmit power at its maximum level (DPC Level 2), are:

In Figure 3.2-A, depicting the average AirCell signals received at the terrestrial sites for all six altitudes, the following results are observed:

- At 0 to 4 miles from the terrestrial site, the strongest signals are received within the -87 to -94 dBm range with the aircraft at 2,000 ft.
- At 5 to 21 miles from the terrestrial site, the strongest signals are received within the -95 to -105 dBm range with the aircraft at 5,000 ft.
- At 22 to 54 miles from the terrestrial site, the strongest signals are received within the -97 to -110 dBm range with the aircraft at 20,000 ft.

- At 0 to 21 miles from the terrestrial site, the strongest signals are received from the lower altitudes (ie. 2,000 ft & 5,000 ft); and at 22 to 80 miles away, the stronger signals are received from the higher altitudes (ie. 20,000 & 35,000 ft).
- At 6 to 55 miles from the victim terrestrial site, the average signal strengths, as measured at the victim terrestrial site, are within ± 5 dB of each other for all altitudes tested except the 2,000 ft altitude test.
- Even at distances far away from the victim site, the received signal is strong enough to cause harmful interference to the terrestrial site. At 75 to 80 miles from the terrestrial site, the average signal strength received is within the -98 to -111 dBm range for aircraft at 20,000 & 35,000 ft, for the horizontally polarized terrestrial antenna.
- The AirCell signal levels received at the terrestrial sites from the flight test at 10,000 ft. for the Piston and Jet aircraft, exhibited similar results, as observed in Figure 3.2-A. Only slight variations are observed; no significant differences are observed. However, in test results for the Oak Hill and Swainton terrestrial sites in the appendix section 9.5, the Piston aircraft exhibited slightly lower received signals at the terrestrial site, by a factor of 3 to 4 dB in some cases.[9]

As observed in Figure 9.5-K through Figure 9.5-WW of the Phase 1 Test Results in Appendix Section 9.5, the AirCell signals received at the terrestrial cell sites were in the following received signal ranges,[10] as listed in Table 3.2-A below. The highest signals were received with the AirCell airborne mobile between 1 and 10 miles away from the terrestrial cell sites and within the main horizontal beam pattern of the terrestrial antenna.

Table 3.2-A Phase 1 Test Results – Received Signals Ranges per Terrestrial Antenna Type

Terrestrial Antenna Type	Received Signal Ranges
H-POL Test Antenna *[1]	-72 dBm to -126 dBm
SL45 Test Antenna *[1]	-78 dBm to -126 dBm
V-POL Test Antenna *[1]	-86 dBm to -126 dBm
OMNI Test Antenna *[1]	-89 dBm to -126 dBm
Oak Hill Cell, Sector 1	-96 dBm to -122 dBm *[2]

[9] The piston aircraft has the VOR style AirCell mobile antenna system, as specified by AirCell, with VOR antennas on both sides of the aircraft's horizontal stabilizer. AirCell uses a splitter to feed these 2 antennas, having a loss of approximately 3 to 4 dB.

[10] All signal levels in this report are referenced to the input of the cell site (hatch plate reference). In all Phase 1 tests, the receiver test equipment at the terrestrial cell sites performed measurements at 1 second intervals (using linear averaging), and in post-processing, this data was merged with RF Trace data with 2 second intervals, which results in 2 second data intervals. In this data, all signal measurements occur during an active AirCell call.

Swainton Cell, Sector 1	-106 dBm to -130 dBm *[3]
Swainton Cell, Sector 3	-107 dBm to -130 dBm *[3]

Notes for Table 3.2-A above:

1. The four terrestrial Test Antennas listed in the table above are located at the Marlboro cell site. The results for these antennas can be compared directly to each other, since they have the same orientation to the aircraft. The test receiver's sensitivity at this location is -126 dBm.
2. In the Phase 1 results for the Oak Hill cell site, the maximum RSSI level is lower than the V-POL, however the average and 90% RSSI levels are slightly higher. In these cases, the closest distance between the AirCell airborne mobile and the Oak Hill cell site was between 16 to 40 miles, depending on the aircraft altitude, while a AirCell call was maintained. The test receiver's sensitivity at this location is -122 dBm.
3. In the Phase 1 results for the Swainton cell site, these RSSI levels are lower than the others, due to less coverage provided by the AirCell system in the vicinity of the Swainton cell site, and the gamma sector antenna azimuth pointing away from the majority of the flight paths. The test receiver's sensitivity at this location is -130 dBm.

In these exhibits, Figure 9.5-K through Figure 9.5-WW, the results were processed and the data evaluated from the following perspectives. The "Received Signal Data" are the individual signal level measurements, displayed as light blue data points. The "Average Signal Level" represents the arithmetic mean of the received signal strength over 1 mile increments, displayed as the blue line. The "90% Signal Level" represents the 90th percentile of measured signal level for each 1 mile interval from the terrestrial site, displayed as the red line. In other words, 90% of the recorded signal strength readings are at or below this signal level, and 10% of the readings are above this level. This is a standard statistical representation for a normal distribution of data points. The "90% Signal Level" also represents the stronger signal levels received at the terrestrial site, which occur while the aircraft is in the main horizontal beam pattern of the terrestrial antennas. The logarithmic signal level represents a best-fit line in a log-distance format, and is displayed as a black line.

In these exhibits, at arc distances of 2, 5, 10, 20, 40, and 80 miles from the Marlboro site, the signal levels are received at the Marlboro terrestrial test antennas from aircraft in all directions around the site; while in-between these distances represent the aircraft flying toward or away from the Marlboro site. In some flight tests, the aircraft was outside the main horizontal beam pattern of the terrestrial panel test antennas while traversing between the arc patterns, which is observed in the graphs at 2,000 ft. with reduced signal levels during these distances.[11]

[11] This is also the case for tests at 10,000 ft. with the Navajo Aircraft using flight paths traversing the arcs outside the main horizontal beam pattern of the terrestrial panel test antennas, between the arcs of 2, 5, 10, 20 and 40 miles. In the other fight tests with DPC disabled, the flight paths between the arcs patterns were within the main horizontal beam pattern of the terrestrial panel test antennas. The terrestrial panel test antennas are installed at the Marlboro site, with their antenna azimuths pointing west (270 degrees from True North reference).

The following is observed from the flight test results in Appendix Section 9.5:

- When the airborne mobile is close to the victim terrestrial site, the received signal strengths are the strongest. The only exception is when the aircraft is directly above the terrestrial site or at distances less than approximately 1 mile, the received signal strength is lower due to "nulls" in vertical antenna pattern of the terrestrial antenna and airborne mobile antenna system.[12] The terrestrial antenna pattern "null" directly above the antenna is approximately 30 dB to 35 dB lower than the antenna gain in the main beam.
- As the distance between the airborne mobile and the victim terrestrial site increases, the AirCell signal strength received at the terrestrial site decreases. The received signal strength is a function of the propagation loss, or radial distance (r) from the terrestrial site, and its incident angle within the vertical gain pattern of the terrestrial antenna. After the propagation loss and path loss through the terrestrial antenna pattern, the resultant signal strength received at the terrestrial site is observed to decrease at a rate of approximately $1/r$ to $1/r^2$, as the aircraft increases its distance from the terrestrial site.[13] At lower altitudes and farther distances, the decrease is approximately $1/r^2$; and at higher altitudes and closer distances, the decrease is approximately $1/r$. This is due to incident angle of the incoming signal, as the aircraft increases its distance from the terrestrial site.
- The horizontal (H-POL) and slant 45 degree (SL45) polarized terrestrial antennas received the strongest AirCell signal levels.

Analysis of the Phase 1 test results shows that the worst case received signal strengths occurred when terrestrial cell sites were equipped with horizontally polarized antennas. It was originally anticipated that this would be the case since the AirCell system uses horizontally polarized antennas. For example, see Figure 3.2-B and Figure 3.2-C depicting the average AirCell signal received at the terrestrial site for all seven terrestrial antennas.

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[12] The AirCell mobile antenna has "nulls" in its vertical pattern, as well. The piston aircraft's VOR antenna is mounted directly above its horizontal stabilizer, which reflect the signals in other directions, and creates a "null" in the pattern directly below. AirCell states that its other mobile antenna (belly-mounted version) also has a null below it, which is built into the antenna.

[13] A decrease at the rate of $1/r^2$ is equal to a reduction in signal strength of 20 dB per decade, or 6 dB per octave. And, $1/r$ is equal to a reduction in signal strength of 10 dB per decade, or 3 dB per octave. Line-of-sight propagation decreases at a rate of $1/r^2$, however the received signal is also a function of the incident angle of the signal received and its associated gain within the vertical antenna pattern, in that direction. For example, in figure Figure 9.5-O, at the octave interval of 20 and 40 miles, it can be observed that the received signal strength (Log. Curve) is -108 dBm and -110 dBm, respectively. This is a decrease of only 2 dB, when line of sight propagation should decrease at a rate of 6 dB per octave. Upon inspection of the vertical antenna pattern, for the respective incident signal angles, the antenna gain for the 40 mile distance is approximately 4 dB stronger, which makes up the difference.

Based on Phase 1 test results, additional observations relative to the polarization of the terrestrial antennas, are:

- The horizontally polarized terrestrial panel antenna (H-POL) exhibited the highest received signal levels from airborne units, as expected. The signal strengths received by the H-POL terrestrial antenna were similar to the levels received by the serving AirCell base station antenna at the Marlboro site.[14] Terrestrial cellular systems using this type of antenna will exhibit approximately 0 dB of isolation from the AirCell signals.
- The "Slant-45" polarized terrestrial panel antenna (SL45) received AirCell signal strengths on average 3-4 dB lower than the horizontally polarized terrestrial antenna (H-POL). These were the second strongest signals received of the four terrestrial test antennas. Terrestrial cellular systems using this type of antenna will exhibit approximately 0 to 4 dB of isolation from the AirCell signals.[15]
- The vertically polarized terrestrial panel antenna (V-POL) received AirCell signal strengths on average 14-15 dB lower than the horizontally polarized terrestrial antenna (H-POL). These were the third strongest signals received of the four terrestrial test antennas. Terrestrial cellular systems using this type of antenna will exhibit approximately 14 to 15 dB of isolation from the AirCell signals.
- The vertically polarized terrestrial omni-directional antenna (OMNI) received AirCell signal strengths on average 15-16 dB lower than the horizontally polarized terrestrial antenna (H-POL). These were the lowest signals received of the four terrestrial test antennas. Terrestrial cellular systems using this type of antenna will exhibit approximately 15 to 16 dB of isolation from the AirCell signals.
- The standard deviation of these isolation figures are observed between 6 to 7 dB for the H-POL to vertically polarized antenna isolation, and 2 to 3 dB for the H-POL to slant 45-degree antenna isolation.

As observed in figures at the end of this section (in Figure 3.2-D and Figure 3.2-E), the AirCell signal strength received at the terrestrial site varies with respect to its mobile transmit power level (DPC Level). This variation is within 20 dB, with the highest transmit power level of 75 mW (DPC=2), and the lowest power level of 0.75 mW (DPC=7). In these tests, the AirCell DPC was disabled and fixed to its maximum power level. The "DPC Level 2" curve represents the measured data. Since the AirCell DPC

[14] AirCell cell sites and mobile units use horizontally polarized antennas in an effort to provide isolation to terrestrial cellular systems, which typically use vertically polarized antennas.

[15] Terrestrial cellular systems using Slant-45 polarized antennas receive terrestrial signals at approximately 0 dB to 3 dB lower than equivalent antennas with vertical polarization, due to the polarity of the incoming terrestrial signal. In cases when both the terrestrial and AirCell signals are received at the terrestrial site at a level 3 dB lower, the AirCell signals will exhibit approximately 0 dB isolation from the terrestrial signal levels.

level is independent of the distance to the terrestrial site,[16] the signal strength associated with other DPC levels can be modeled by offsetting the signal strength received at the terrestrial cell site with the appropriate 4 dB decrement (DPC attenuation step[17]). By applying this method, the signal strength results of the other DPC levels (i.e., DPC Level 3 to 7) are provided in these figures.[18] Observations from these figures, depicting the average signal strength received at the terrestrial SL45 antenna, within distances of 0 to 55 miles from the terrestrial site, are as follows:

- At the highest power levels (DPC Level 2 & 3), the 90th percentile AirCell signals are received in similar ranges as typical customers using the terrestrial cellular network.[19] The received AirCell signal strength is in the range of -94 to -113 dBm. With this level of interference, terrestrial cellular customers will experience severely degraded C/I ratios (in some cases negative C/I values) causing significant harmful interference to the terrestrial network. As modeled in a case study of a typical flight (provided in section 6), interfering signals received at –114 dBm and above can cause harmful interference to as many as 1,500 terrestrial cell sites and over 30,000 terrestrial phone calls.[20]
- At the lowest transmit power level (DPC Level 7), the 90th percentile AirCell signals are also received at levels that are strong enough to cause harmful interference to the terrestrial system.[21] In this case, the received AirCell signal strength is in the range of -114 to -129 dBm. At higher AirCell mobile transmit power levels (ie. DPC Level 2 to 6) the received AirCell signals are

[16] The AirCell mobile transmit power (DPC Level) is a function of its distance and altitude with respect to its serving AirCell cell site. It is independent of the distance to the victim terrestrial cell site.

[17] The AirCell DPC algorithm adjusts the mobile unit transmitting output power as a function of RSSI (received signal strength) from the serving AirCell site. The range of this variable is DPC=2 through 7, each step being a 4 dB decrement, with step 7 being lowest transmitting power, and step 2 being its maximum transmitting power (equal to approximately 75 mwatts.)

[18] A similar technique is used in the Case Study (Section 6), which models a typical flight path, performs analyses using the received signal strength data at terrestrial sites from AirCell mobiles at DPC level 2, and using the AirCell DPC data from tests with DPC enabled.

[19] Typical terrestrial customer signal ranges received at terrestrial sites are provided in appendix section 9.9.

[20] The results provided are for terrestrial cellular systems employing CDMA technology and Slant 45 polarity antennas. The case study uses an interference analysis point of –114 dBm, based on the results of Phase 2 tests. AirCell signals received in the –94 to –113 dBm range, are above this –114 dBm level, and would cause harmful interference to more terrestrial sites and phone calls than listed in the case study. Results for other terrestrial technologies and antennas are provided in the Case Study section 6.

[21] As provided in the "Results of Phase 2 Tests" in Section 4, harmful interference will occur to AMPS systems at interfering levels of –123 dBm and above, and to TDMA & CDMA systems at interfering levels of –120 dBm and above.

stronger, and the harmful interference to the terrestrial network is worse than it is at DPC level 7, as provided in the results of Phase 2 tests in section 4.

- At DPC Level 2, the average and 90th percentile AirCell signals received at the terrestrial site are in the range -103 to -116 dBm, and -94 to -109 dBm, respectively.
- At DPC Level 3, the results are 4 dB lower than DPC=2, the average and 90th percentile AirCell signals received are in the range -107 to -120 dBm, and -98 to -113 dBm, respectively.
- At DPC Level 4, the results are 8 dB lower than DPC=2, the average and 90th percentile AirCell signals received are in the range -111 to -124 dBm, and -102 to -117 dBm, respectively.
- At DPC Level 5, the results are 12 dB lower than DPC=2, the average and 90th percentile AirCell signals received are in the range -115 to -128 dBm, and -106 to -121 dBm, respectively.
- At DPC Level 6, the results are 16 dB lower than DPC=2, the average and 90th percentile AirCell signals received are in the range -119 to -132 dBm, and -110 to -125 dBm, respectively.
- At DPC Level 7, the results are 20 dB lower than DPC=2, the average and 90th percentile AirCell signals received are in the range -123 to -136 dBm, and -114 to -129 dBm, respectively.

As observed in Figure 9.4-A through Figure 9.4-C, of the Phase 1 Test Results in Appendix Section 9.4, the strongest AirCell signals are received when the aircraft is located to the west of the Marlboro site, and within the main beam pattern of the terrestrial test panel antennas.

In addition, as observed in Phase 1 results, the AirCell VOR mobile antenna installed in the piston aircraft (used at altitudes 10,000 ft and below) exhibited “nulls” in its horizontal antenna pattern in the direction of directly toward and away from the aircraft’s direction of flight. This null is observed to be on the order of approximately 8 dB, as compared to the signals received when the aircraft is flying parallel to the terrestrial site. In addition, both of AirCell’s mobile antennas exhibited “nulls” in its vertical pattern. The piston aircraft’s VOR antenna is mounted directly above its horizontal stabilizer, which reflect the signals in other directions, and creates a “null” in the pattern directly below. AirCell states that its other mobile antenna (belly-mounted version) also has a null directly below it, which is built into the antenna.

Figure 3.2-A Phase 1 Test Results, RSSI at Terrestrial Site: H-POL Antenna, All Altitudes, DPC Disabled

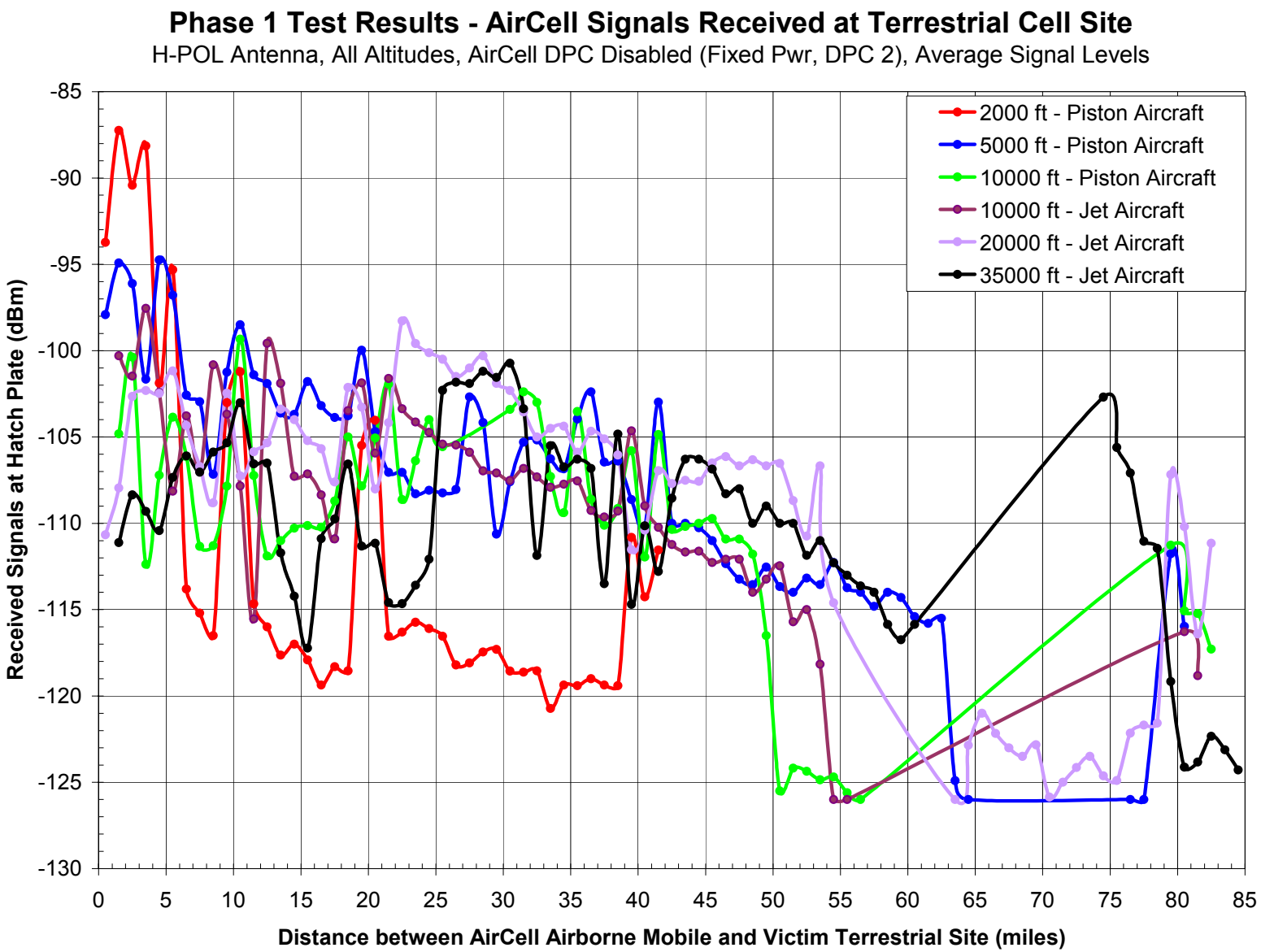


Figure 3.2-B Phase 1 Test Results, RSSI at Terrestrial Site: All Antennas, Piston Aircraft @ 5,000', DPC Disabled

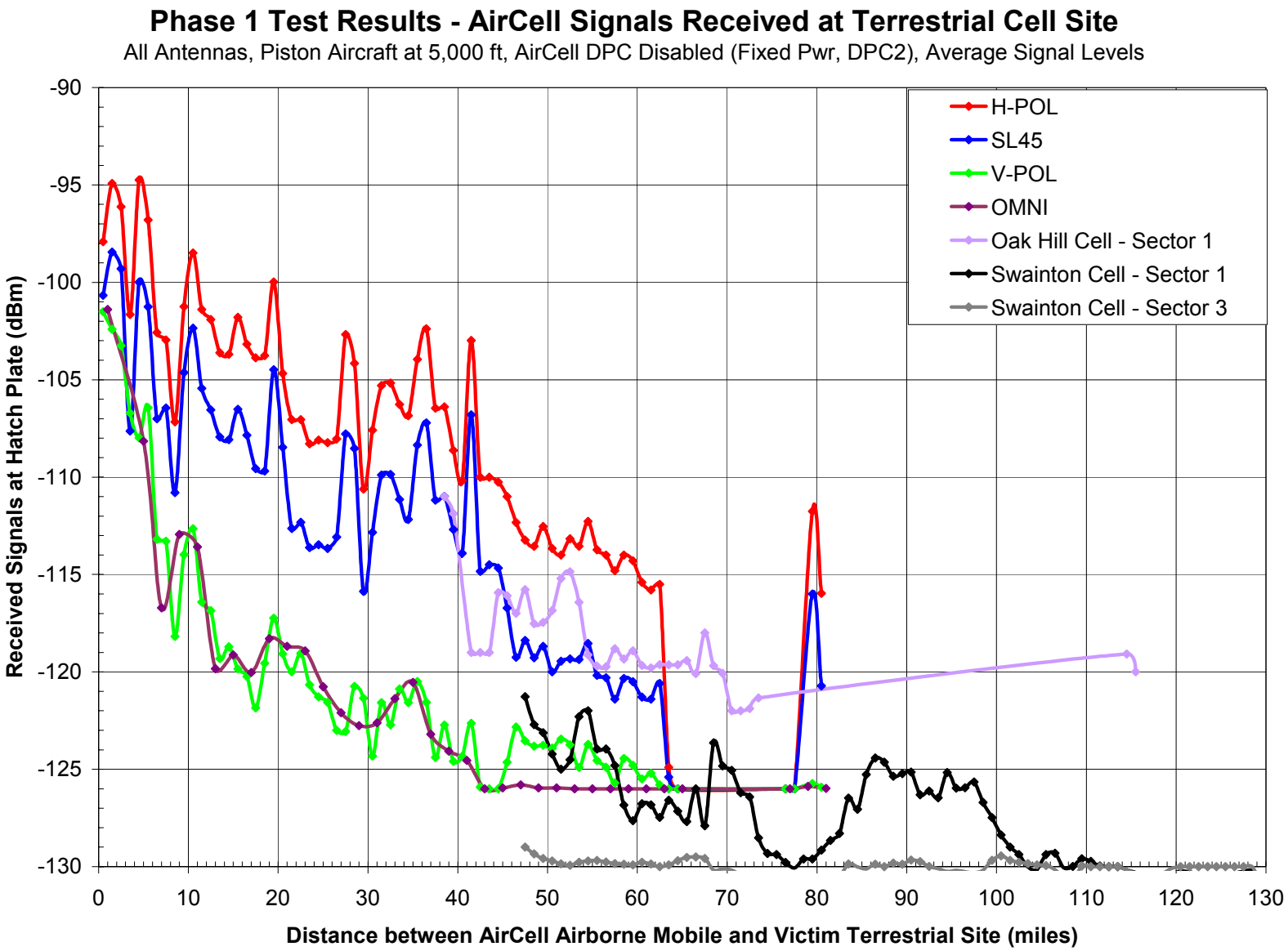


Figure 3.2-C Phase 1 Test Results, RSSI at Terrestrial Site: All Antennas, Jet Aircraft @ 20,000', DPC Disabled

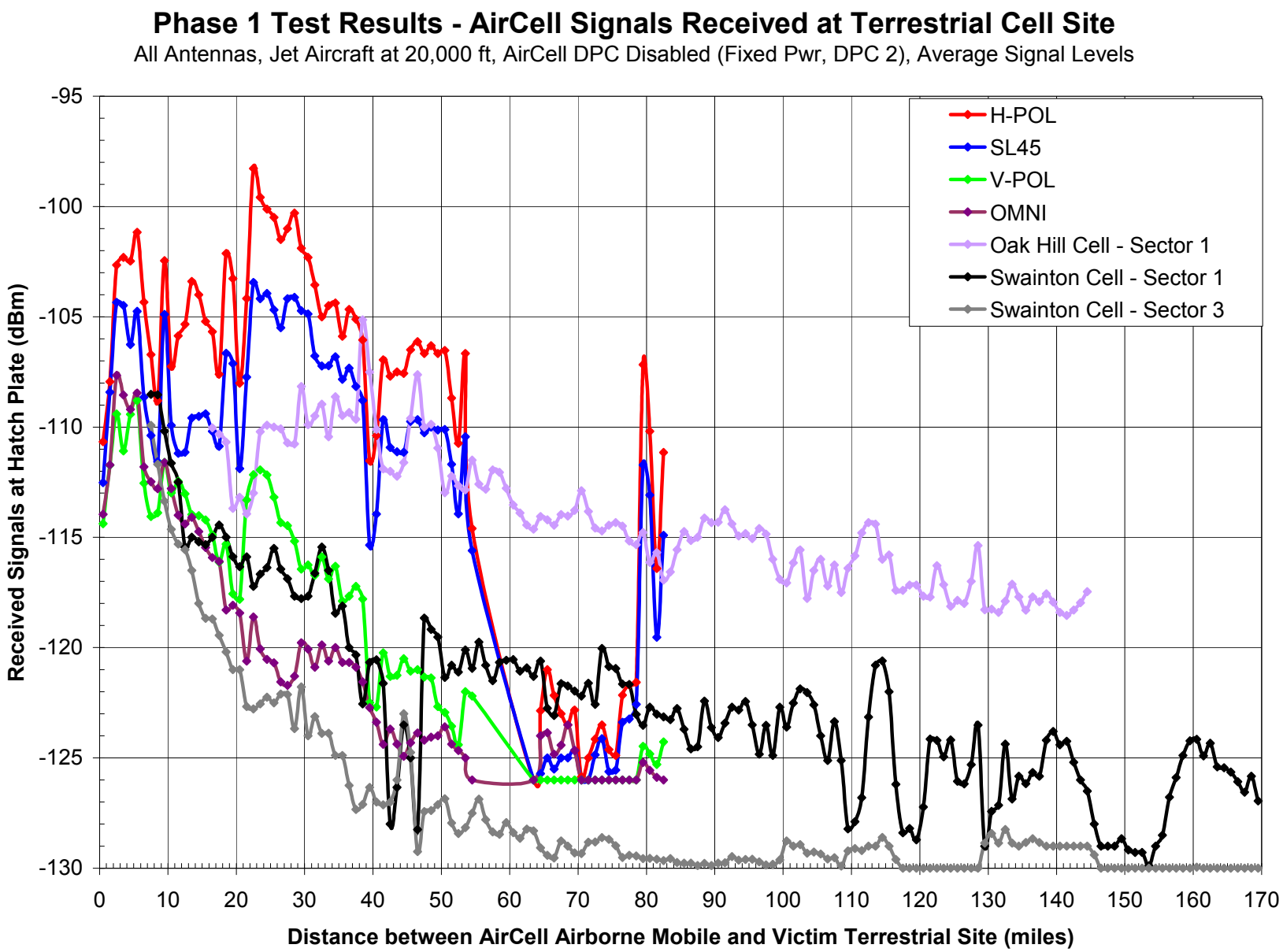


Figure 3.2-D Phase 1 Test Results, Avg. RSSI at Terrestrial Site, DPC 2 to 7: SL45 Antenna, Jet at 20,000', DPC Disabled

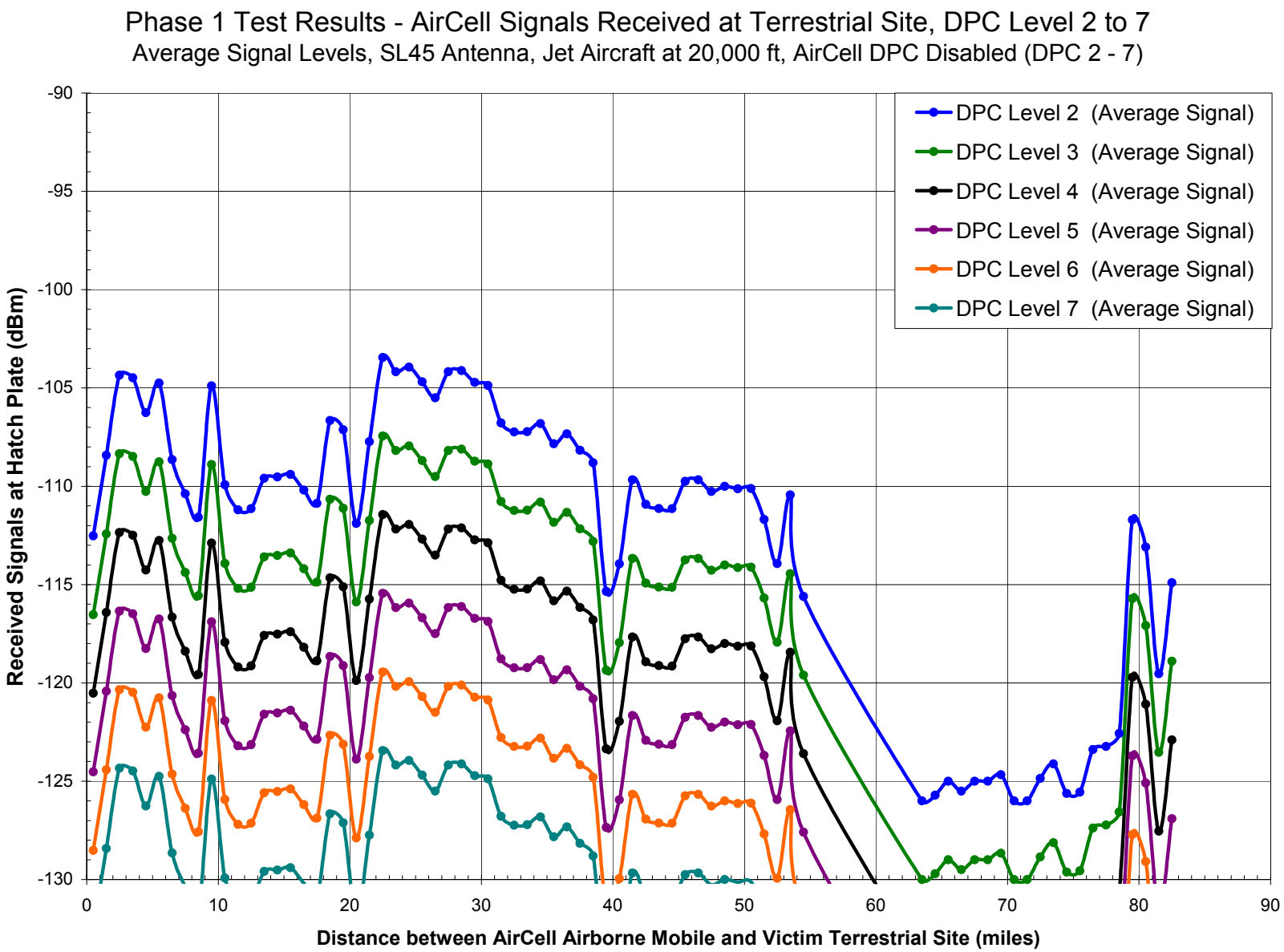
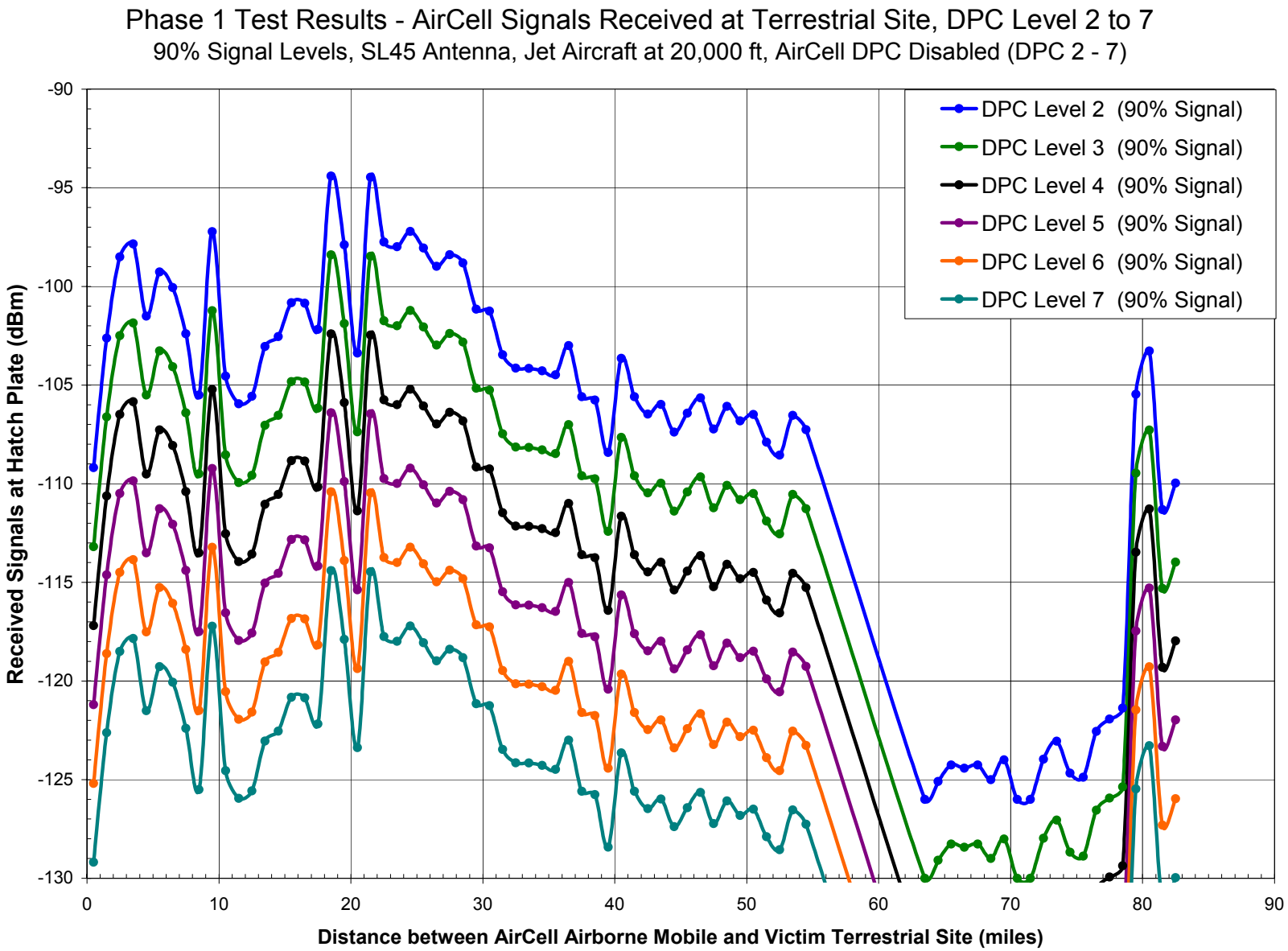


Figure 3.2-E Phase 1 Test Results, 90% RSSI at Terrestrial Site, DPC 2 to 7: SL45 Antenna, Jet at 20,000', DPC Disabled



3.3 Phase 1 Test Results – AirCell Mobile Dynamic Power Control (DPC) Levels

The Phase 1 test results provided in this section were completed with the AirCell mobile phone DPC feature enabled, as specified in the AirCell Compatibility Test Plan in Appendix Section 9.18. For these tests, the serving AirCell cell site is the Marlboro, NJ cell site, which was configured and optimized by AirCell. The purpose of these tests is to collect the AirCell mobile transmit power levels (DPC Levels) for typical flight patterns included in the Phase 1 tests. With these results, the AirCell mobile DPC levels and corresponding distances to the serving AirCell cell site can be observed. The results of these tests are used in additional analyses to determine the potential effects to hundreds of terrestrial cell sites along a typical flight plan, as provided in the case study Section 6. Results of the Phase 1 tests with DPC enabled are provided in graphs at the end of this section, and in the appendix Sections 9.6, 9.7, and 9.8. The flight patterns used in these flight tests are provided appendix section 9.3.

During these flight tests, measurements are collected at 3 terrestrial cell sites. At the Oak Hill and Swainton terrestrial cell sites, measurements are collected on vertically polarized panel cell site antennas, with azimuths pointing toward and away from the flight patterns,[22] as described in the test plan. In addition, measurements are collected at the Marlboro cell site with the H-POL, SL45, V-POL and OMNI terrestrial test antennas.[23]

The maximum power allowed under current FCC waiver limitations for AirCell mobile phones is 75 mwatts, which corresponds to the DPC Level 2.[24] AirCell optimizes and configures the cell sites within its network, and set the Marlboro cell site to utilize a

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[22] For the majority of the results of the DPC enabled flight tests, AirCell signal levels received at the terrestrial cell sites were lower than the DPC disabled tests, due to lower AirCell mobile power levels and a flight path that flew directly toward and over the terrestrial sites. With this flight path, the received signals are more favorable (lower at the terrestrial site) than flying horizontal to the terrestrial site and at a distance that is within 10 miles. The DPC enabled flight tests do not capture these results, whereas the DPC disabled flight tests do capture them.

[23] For these flight tests with DPC enabled, the measurements at the Marlboro terrestrial antenna site represent the best case scenario of a terrestrial site collocated with the AirCell site resulting in lower power levels for the AirCell mobile since its close to its home serving cell site.

[24] The AirCell DPC function adjusts the mobile unit transmitting output power as a function of RSSI (received signal strength) from the serving AirCell site. The range of this variable is DPC=2 through 7, each step being a 4 dB decrement, with step 7 being lowest transmitting power, and step 2 being its maximum transmitting power. The AirCell phone transmit power levels are equal to approximately 75, 30, 12, 5, 2, and 0.75 mwatts, for DPC Level 2 through 7, respectively. The maximum attenuation provided by the DPC function is 20 dB (5 steps x 4 dB per step). These power levels are referenced to the output of the AirCell phone system, which is prior to the main coaxial cable and AirCell mobile antenna used in the aircraft.

maximum DPC Level 3 for mobiles.[25] In Phase 1 flight tests, with this power setting, the AirCell mobile power was in the range of DPC 3 to DPC 7, and the power level DPC 2 was never reached. This is reflected in the graph of AirCell Mobile DPC Percentages, in Figure 3.3-A (Results of all Phase 1 tests with DPC enabled).

Observations from the Phase 1 Test Results, with the AirCell mobile DPC enabled and optimized by AirCell, are:

In Figure 3.3-A, depicting the percentage of time each AirCell mobile DPC level was attained for all flight tests, the following results are observed:

- The AirCell mobile unit was at its maximum power level more often than any other power level. The DPC level of 3, or maximum power as configured for the Marlboro AirCell site, was attained 33% of the time while conducting tests.
- The AirCell mobile unit was at its lowest power level the least amount of time, compared to the other power levels. The DPC level of 7, or lowest power for the AirCell airborne mobile unit was attained 7% of the time while conducting tests.
- There is a greater probability that the AirCell mobile unit will transmit at its higher power levels.[26] This is observed in the results depicted in this figure, with the exception of DPC level 4.

Observations from Figure 3.3-B, and others in Appendix Section 9.6, depicting the AirCell DPC Levels for the Phase 1 flights with DPC enabled are:

- The AirCell mobile power increases (lower DPC value) with increasing distance from its serving AirCell cell site. In general, the AirCell mobile transmits at lower power when closer to its serving cell site, and increases in power until it reaches maximum power at some distance away. This trend is particularly important, as it is more likely to cause interference to terrestrial cellular systems in neighbor markets that are further away. The AirCell phone is more likely to transmit at lower power when it is close to its serving site and within its own market area.[27]

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[25] Other nearby sites in the AirCell network are currently configured for the DPC Level 2, and they are the Martinsburg, WV, Altoona, PA, and Owego, NY AirCell sites. Additional information regarding AirCell cell site parameters and optimization is provided in section 7.6.

[26] The AirCell mobile DPC function is controlled by its serving cell site. The mobile power level is inversely related to the RSSI at the cell site, and directly related to the path loss and distance from the cell site. With line-of-sight propagation decreasing at a rate of $1/r^2$, the mobile transmit power level must increase at a rate of r^2, in relation to the radial distance (r) from its serving cell site. With this rate of increase, there is a greater likelihood of occurrence that the AirCell mobile unit will be at its higher power levels.

[27] The AirCell mobile transmit power (DPC level) is independent of the needs of the terrestrial cellular system, and it is only dependent on the need to maintain sufficient RSSI levels at its serving cell site. Consequently, the AirCell mobile is more likely to be at maximum power and be received at terrestrial neighboring cellular systems at higher power levels.

- Although there are some similarities, the AirCell mobile DPC levels vary across different altitudes and distances. The variation is due to different aircraft orientations to the serving AirCell cell site, and the signal being received at different "lobes" within the antenna pattern of the serving cell site.[28]
- In some cases, the relationship of AirCell mobile power to distance from its serving cell site is observed to be approximately proportionate to the square of the distance from its serving cell site. The increase in mobile transmit power is inversely proportionate to the line-of-sight propagation loss of the airborne mobile with its serving cell site.[29]
- At several altitudes: 5K ft. (Piston), 10K ft. (Piston), 20K ft. (Jet), and 35K ft. (Jet), the maximum AirCell mobile transmit power, DPC Level 3 for Marlboro, was attained within 10 miles or less from the serving AirCell Marlboro site.
- On average, maximum transmit power, DPC Level 3 for Marlboro, was consistently maintained at distances approximately 55-60 miles from the serving AirCell site.
- On average, the lowest transmit power is typically reached close to the serving AirCell site, then higher power at distances of 10-30 miles, then lower power at distances of 30-45 miles, and finally increasing to maximum power at distances of 55+ miles from the serving AirCell site.
- The maximum range of the AirCell system is observed to be approximately 135 miles from the serving AirCell cell site, as observed in the flight test at 35,000 ft.[30] The range of the AirCell system is observed to be between 72 to 93 miles from the serving AirCell cell site for flights at 4,000 and 5,000 ft., and between 97 to 106 miles for flights at 10,000 and 20,000 ft.

The graphs in Figure 3.3-B and Appendix Section 9.6 depict the results of AirCell mobile DPC Levels for the Phase 1 flight tests. In the graphs depicting the results of individual

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[28] The serving AirCell Marlboro cell site uses 2 receive antennas with 15 feet of vertical diversity, as specified by AirCell. The AirCell cell site antennas are horizontally polarized with an offset omni-directional type pattern, with approximately 11 dBd gain. One antenna is electrically up-tilted 1.5 degrees and the other up-titled 4 degrees. This is AirCell's "standard" cell site antenna configuration. The antenna model is Scala SL11-885.

[29] As the AirCell mobile travels farther away from its serving cell site, the path loss is greater, and the mobile must transmit at higher power levels to maintain the call. In some cases, the path loss is observed to follow line-of-sight propagation loss, which is $1/r^2$ (r = radial distance from serving site), or 20 dB loss per decade. For example, an increase in mobile power level from DPC 5 to DPC 4, which is a 4 dB increase in power, occurs at approximately 1.58 times the distance from its serving cell site, or (4 dB = 20 * log 1.58).

[30] The maximum range is the farthest distance, of the airborne AirCell phone from its serving cell site, that an AirCell call can be maintained on its system. In these tests, the serving cell site's setting for maximum mobile transmit power is DPC level 3, or approximately 30 mwatts, as configured and optimized by AirCell. Other AirCell sites utilize 4 dB higher mobile transmit power settings, or approximately 75 mwatts, and are expected to exhibit larger coverage ranges.

flights, the “DPC Level Data” and the “Average DPC Level” are provided. The “Average DPC Level” represents the arithmetic mean of the “DPC Level Data” over 2 mile increments.

In Figure 3.3-C and Figure 9.7-A, the AirCell Mobile DPC Levels at Low Altitudes are depicted for piston aircraft landing at Somerset (SMQ) and jet aircraft landing at Allentown-Bethlehem (ABE) airports, respectively. Observations from these figures are:

- At 30 miles from the AirCell cell site, the minimum altitude to maintain an AirCell phone call is approximately 500 ft. above ground level; and at 67 miles from the AirCell cell site, the minimum altitude is approximately 1,700 ft. above ground level.
- In some cases, an increase in AirCell mobile power is observed when the aircraft is descending to lower altitudes. This depends on the aircraft altitude and distance from its serving site, as well as the AirCell cell site vertical antenna pattern, and attenuation from tree line obstructions at low altitudes.[31]

The RSSI graphs in Figure 3.3-D through Figure 3.3-F, and in Appendix Section 9.8, depict the AirCell signal levels received at the Terrestrial Cell Sites for the Phase 1 flight tests. In these exhibits, the results were processed and the data evaluated from the following perspectives. The received signal data is displayed as data points with color representing the AirCell DPC level. The “Average Signal Level” represents the arithmetic mean of the received signal strength over 2 mile intervals, and is displayed as the blue line. The “90% Signal Level” represents the 90th percentile of measured signal level for each 2 mile interval from the terrestrial site, and is displayed as the red line. In other words, 90% of the recorded signal strength readings are at or below this signal level, and 10% of the readings are above this level. This is a standard statistical representation for a normal distribution of data points. Observations from these figures are:

- In some cases, there was no coverage provided by the AirCell system, up to 40 miles from the terrestrial cell site.
- These flight tests represent the best-case aircraft orientation to the terrestrial cell sites, with lower received signals at the terrestrial sites, due to the aircraft flight path directly over the victim terrestrial cell site, or within approximately 1 mile of the terrestrial site. In these cases, the “nulls” in the vertical antenna pattern of the AirCell mobile and victim terrestrial cell site can combine to more than 50 dB of attenuation.[32]

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[31] An increase in mobile transmit power was not observed in all cases. In other cases, the AirCell phone call dropped before the DPC function was able to power the phone up, when descending to very low altitudes.

[32] The “nulls” in the vertical pattern of the terrestrial site panel antenna (pointing directly above) is between 30-35 dB, and the AirCell mobile antenna (pointing directly below) is estimated to within 15-20 dB.

- In some cases with the piston aircraft and AirCell VOR mobile antenna, the aircraft orientation to the terrestrial cell sites yielded lower received signals at the terrestrial sites, due to the aircraft flight path pointing in the direction of the victim terrestrial cell sites. In these cases, the results exhibited approximately 8 dB lower signals received at the terrestrial cell sites.[33] This was due to reduced gain in the horizontal pattern of the AirCell VOR mobile antenna, in the direction of the flight path.
- In some cases, the received signal at the terrestrial site is lower due to the AirCell mobile transmit power being at lower power levels (larger DPC value), particularly when the AirCell mobile is close to its home serving site.
- When the AirCell mobile transmit power is higher (lower DPC levels) the received AirCell signal levels at the terrestrial cell sites are stronger.
- When the AirCell mobile phone is located within 50 to 70 miles the Swainton terrestrial site, the AirCell mobile transmit power is at its maximum level (DPC 3 for Marlboro site) most of the time. This is expected as the Swainton site is located 88 miles from the AirCell serving site, and is representative of a terrestrial cell site in a neighboring cellular market.
- The AirCell signals received at the 3 terrestrial cell sites are in the range of –102 to –130 dBm. In general, the stronger signals are received when the AirCell mobile phone is closer to the terrestrial cell sites and at higher power levels. However, even at lower power levels, there are times the AirCell signal is received at strong levels, as indicated in the results for Marlboro's Slant45 and H-POL test antennas.
- The AirCell signals received at the Oak Hill terrestrial cell site are in the range of –108 to –110 dBm, for the piston aircraft flight at 10,000, and extend to a distance of 48 miles from the Oak Hill site for the flight at 10,000 ft.
- The AirCell signals received at the Oak Hill terrestrial cell site are in the range of –108 to –115 dBm, for flights at 5,000 ft and above, and extend to a maximum distance of 107 miles from the Oak Hill site for the flight at 35,000 ft.
- The AirCell signals received at the Swainton terrestrial cell site are in the range of –106 to –110 dBm, for flights at 10,000 and 20,000 ft., and extend to a maximum distance of 10 miles from the Swainton site for the flight at 20,000 ft.
- The AirCell signals received at the Swainton terrestrial cell site are in the range of –106 to –115 dBm, for flights at 4,000, 10,000 & 20,000 ft, and extend to a maximum distance of 28 miles from the Swainton site for the flight at 4,000 ft.
- The AirCell signals received at the Marlboro terrestrial H-POL antenna are in the range of –102 to –110 dBm, for flights at all altitudes, and extend to a maximum distance of 44 miles from the terrestrial site for the flight at 4,000 ft.
- The AirCell signals received at the Marlboro terrestrial SL45 antenna are in the range of –102 to –110 dBm, for flights at all altitudes except 4,000 ft., and extend

[33] In these cases, an approximately 8 dB reduction in signal strength received at the terrestrial cell site is observed in Phase 1 flight tests with DPC disabled, in section 3.2.

to a maximum distance of 42 miles from the terrestrial site for the flight at 4,000 ft.

- The AirCell signals received at the Marlboro terrestrial OMNI and V-POL antennas contain a few sporadic data points in the –105 to –110 dBm range when within 1-2 miles of the terrestrial site, for the flight at 5,000 ft. For vertically polarized antennas collocated at the Marlboro AirCell site, the received signal levels fall off quickly after 5 to 10 miles away, which is expected due to the orientation of the flight path and the collocation.
- At the Marlboro terrestrial site, AirCell signal levels are received at lower power levels since the mobile is close to its home serving site. With the same flight path orientation to the terrestrial site, but further away from the AirCell mobile's serving site, will yield increased AirCell signal levels at the terrestrial site. For example, in cases where the AirCell mobile is further away from its serving site and at maximum power level (DPC 2), with these flight test results for the Marlboro H-POL antenna, the signal levels received at the terrestrial site would have been as high as –83 dBm at 3 miles, and –85 dBm at 4 miles from the terrestrial site.
- When analyzing the results of the flight tests with DPC enabled, the AirCell mobile DPC levels as well as the RSSI at the terrestrial site must be considered to evaluate the full interference potential of the AirCell system.

Figure 3.3-A Phase 1 Test Results, AirCell Mobile DPC Percentages, DPC Enabled

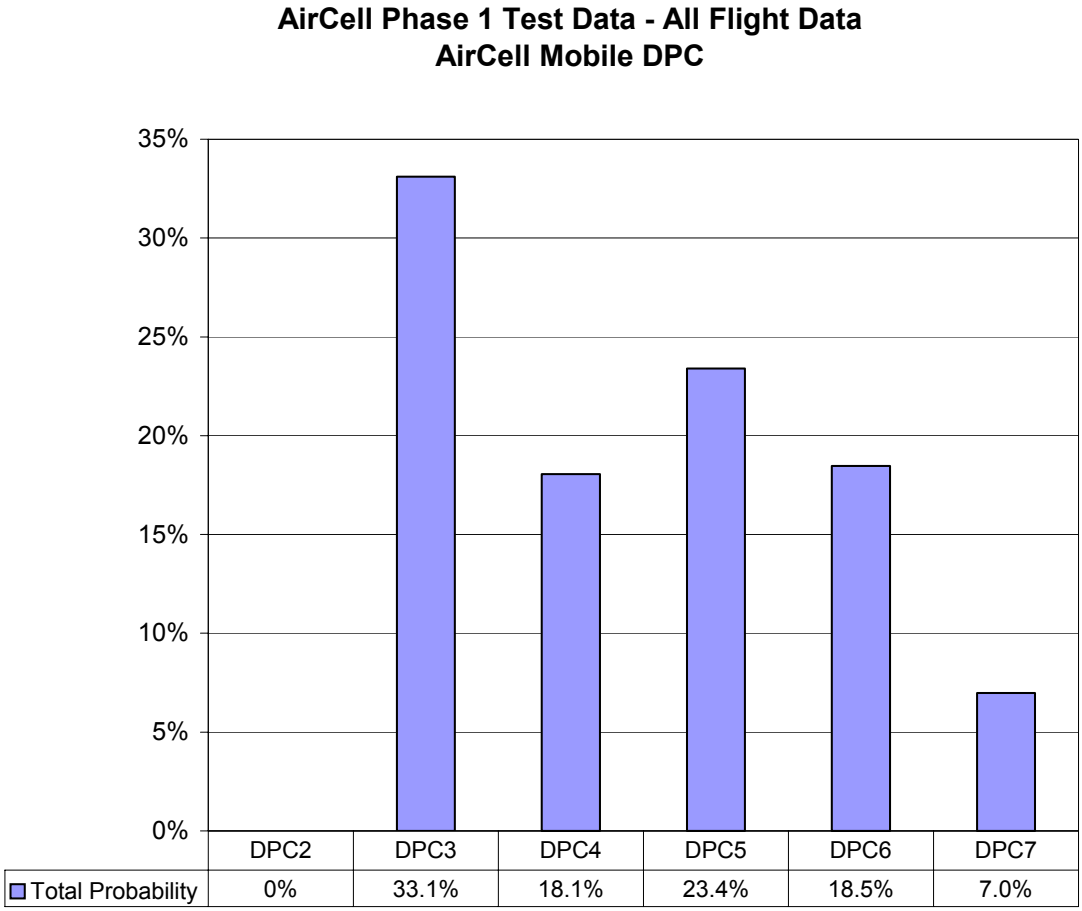


Figure 3.3-B Phase 1 Test Results, AirCell Mobile DPC Levels: All Altitudes, Piston & Jet Aircraft, DPC Enabled

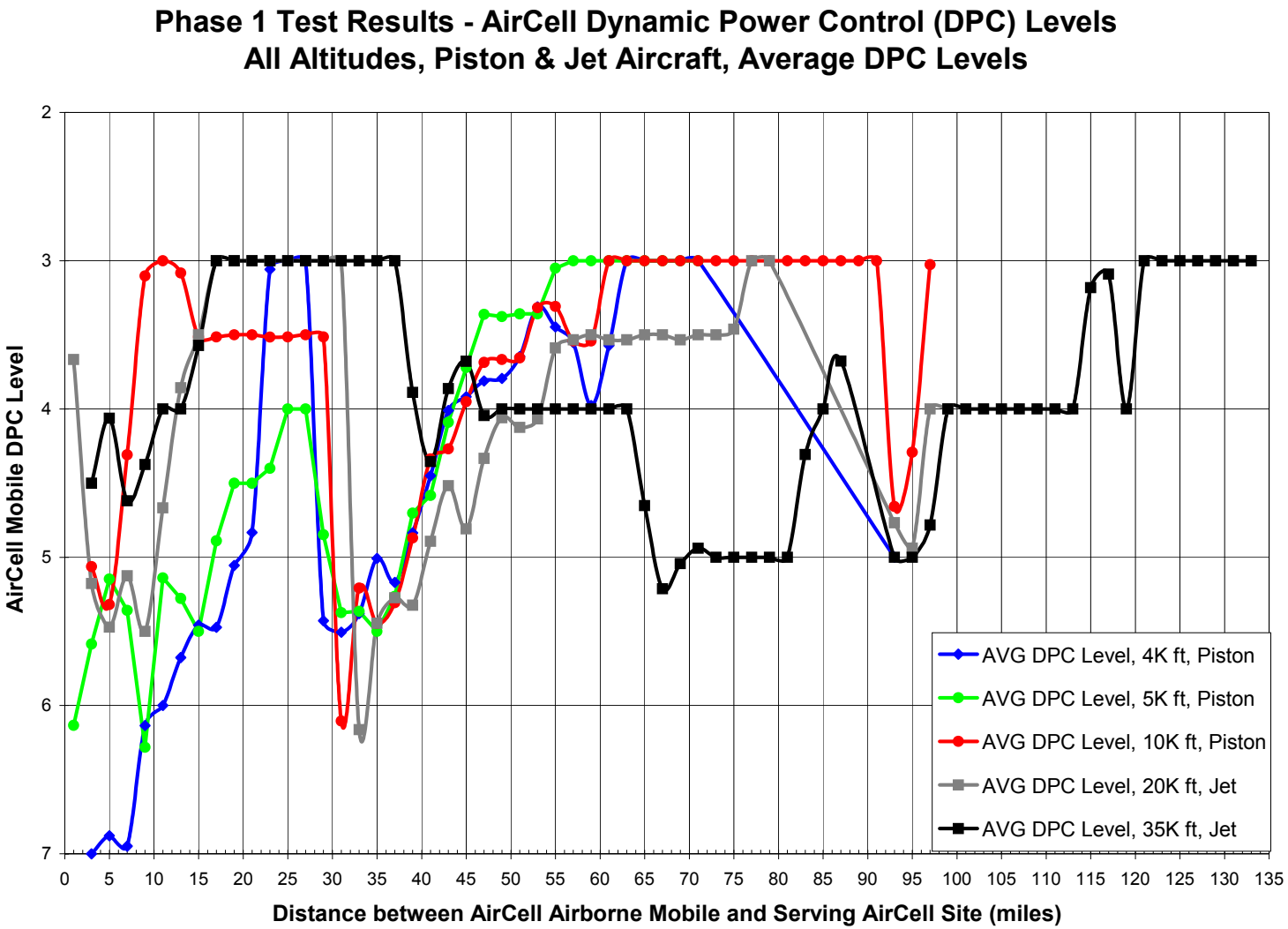


Figure 3.3-C Phase 1 Test Results, AirCell Mobile DPC Levels at Low Altitudes: Landing at SMQ Airport, DPC Enabled

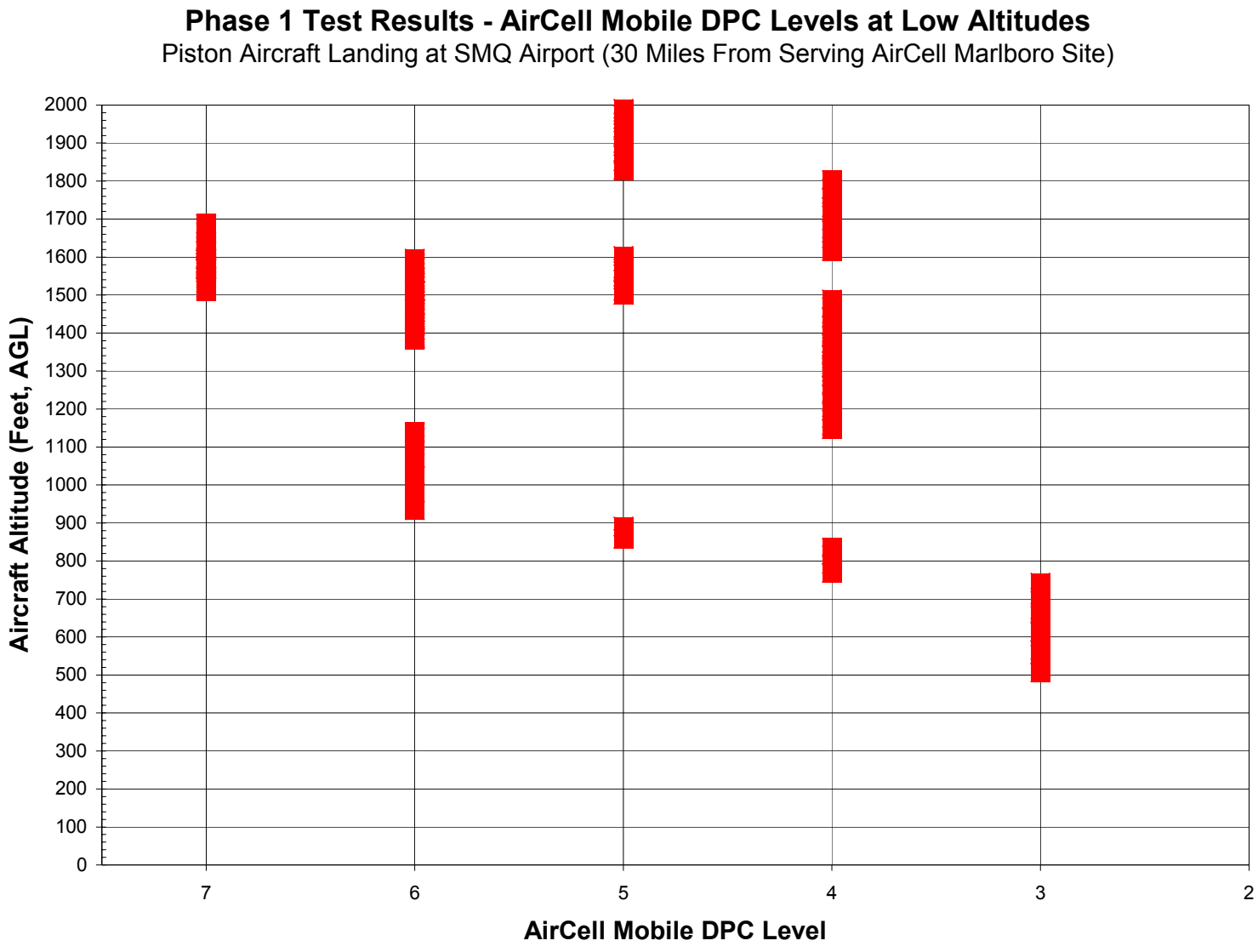


Figure 3.3-D Phase 1 Test Results, RSSI at Terrestrial Site: Oak Hill Sector 1, Piston Aircraft @ 10,000', DPC Enabled

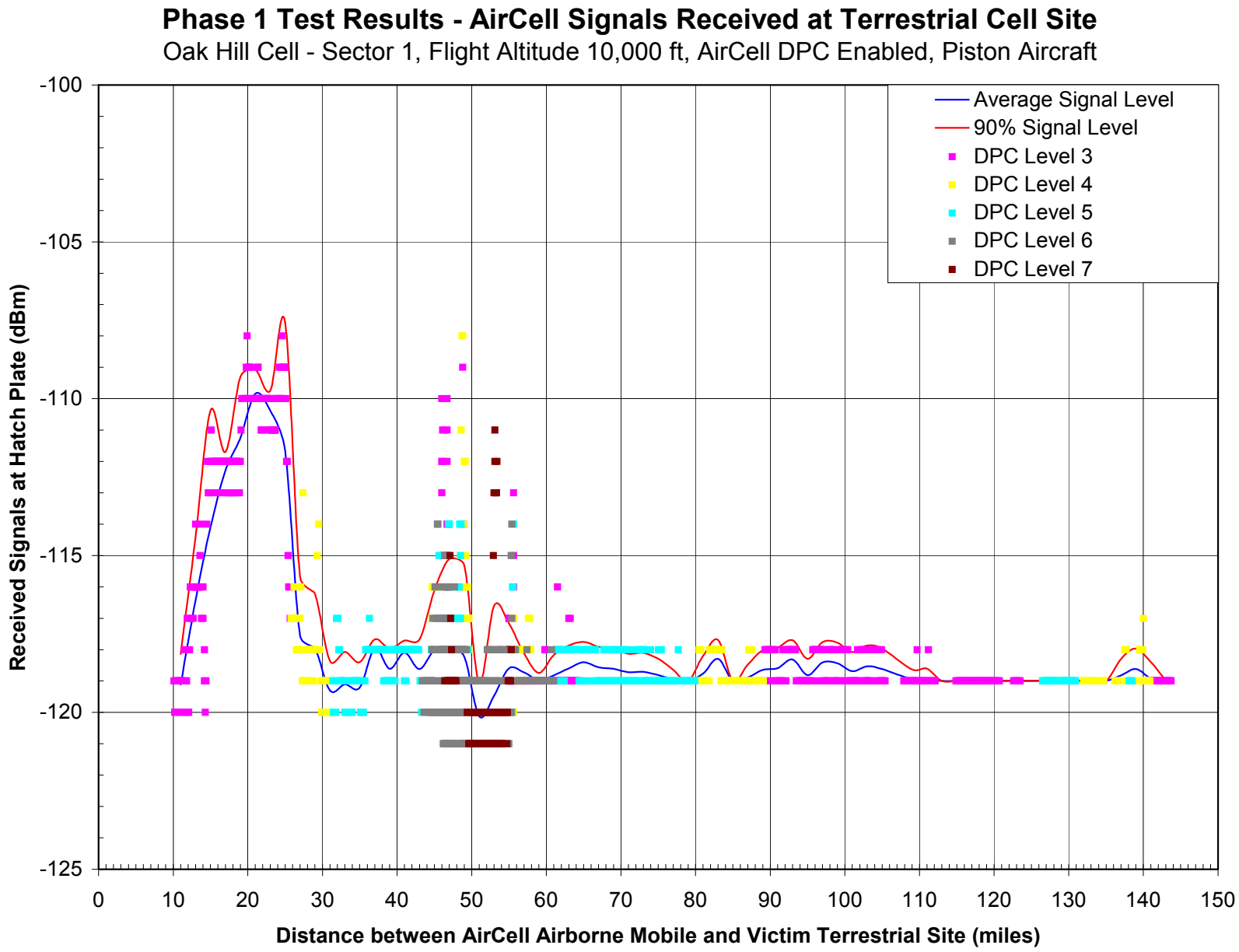


Figure 3.3-E Phase 1 Test Results, RSSI at Terrestrial Site: SL45 Antenna, Piston Aircraft @ 10,000', DPC Enabled

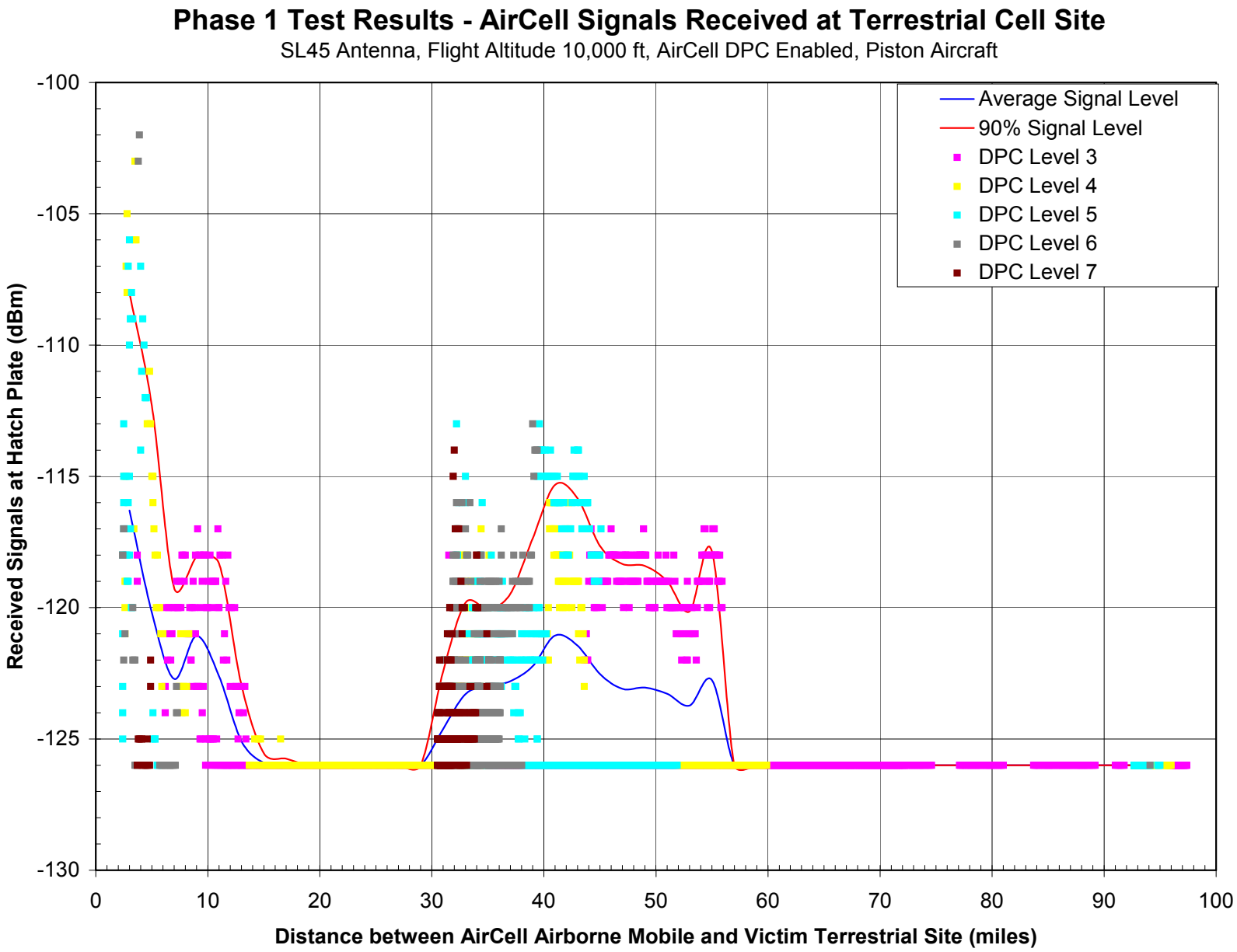
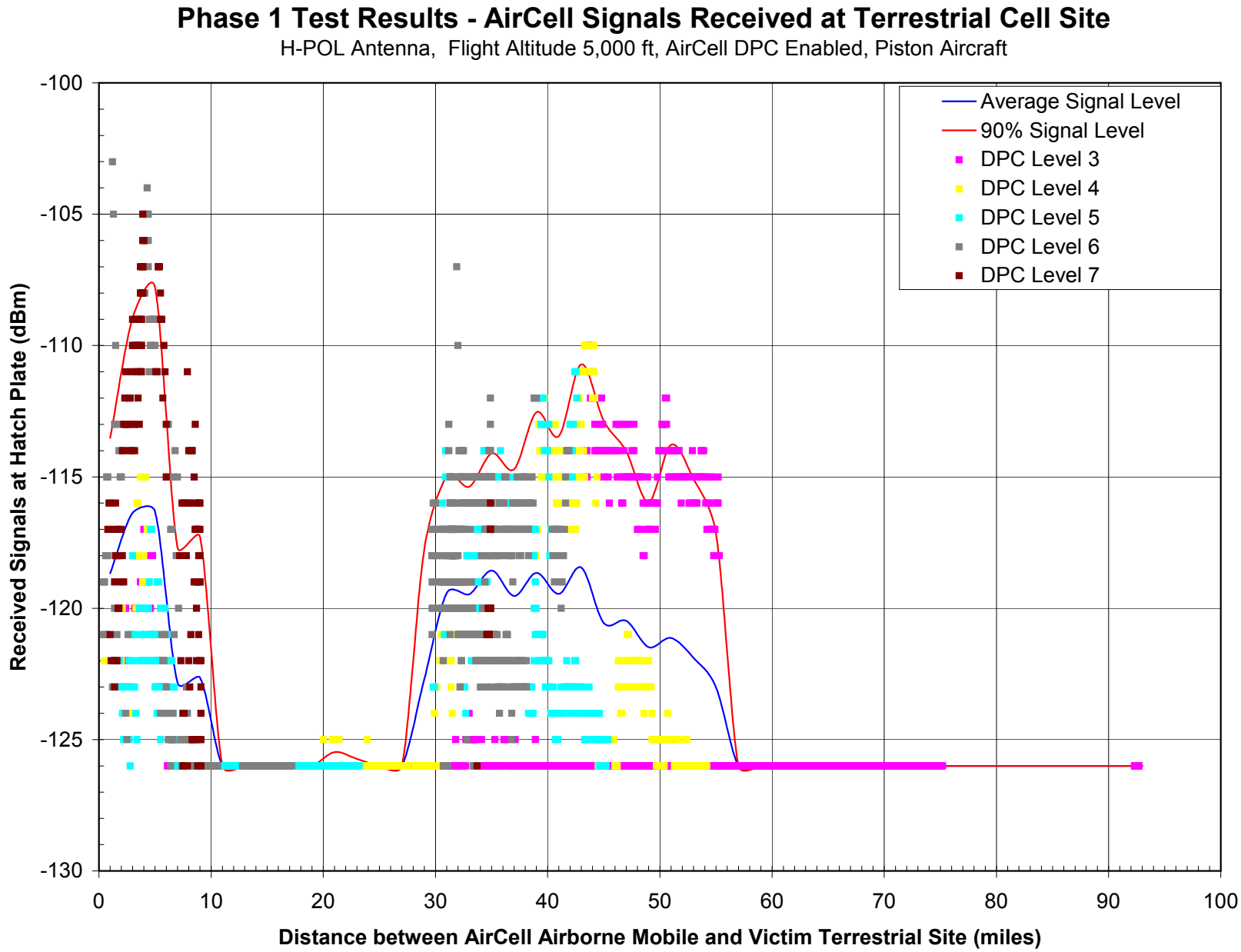


Figure 3.3-F Phase 1 Test Results, RSSI at Terrestrial Site: H-POL Antenna, Piston Aircraft @ 5,000', DPC Enabled



4 Results of Phase 2 Tests

4.1 Introduction

In Phase 2 of the "AirCell Compatibility Test Plan", tests were performed with simulated AirCell signal levels injected into the receive path of representative terrestrial cell sites. In these tests, the cellular system performance metrics were monitored and recorded to determine whether harmful interference is occurring. These tests were performed within the coverage area of the suburban terrestrial test cell site, and with the cell site operating under normal day-time market conditions. Drive tests were utilized to cover an even distribution of roads within the cell site footprint, and match the typical signal levels of normal cellular customers. By performing these tests for each technology (AMPS, TDMA & CDMA) used by the cellular network operators in this area, analyses can be performed to determine the potential effects of the interference.

Tests with AMPS technology were performed with injected interfering signals on AMPS voice channels. Tests with TDMA technology were performed with injected interfering signals on a TDMA radio channel, containing 1 control and 2 voice timeslot channels. Tests with CDMA technology were performed with injected interfering signals, as follows, and under normal day-time operating and market noise conditions: 1 signal on CDMA Carrier, 2 signals on CDMA Carrier, 1 signal on the Guard Band, and 2 signals on the Guard Band; in separate tests. Additional CDMA drive tests were performed with 1 injected interfering signal on the CDMA carrier, and under normal cell site operating and 3 dB system loaded conditions. In addition, stationary CDMA capacity tests were performed with the same injected signal scenarios, as stated above.

All Phase 2 tests were performed with the cell site configured, operating and performing in its normal mode. In addition, the actual cell site operating noise was utilized in these tests, due to the tests being performed on "live" cellular networks, during normal business day-time operation. To review a detailed description of the test procedures and methods used in the Phase 2 tests, refer to the AirCell Compatibility Test Plan in Appendix Section 9.18.

This section focuses on the results of the Phase 2 tests performed under the AirCell Compatibility Test Plan. The Phase 1 tests results determined the signal levels that could be received at a terrestrial cell site from the AirCell operating mobile unit. These signal levels are used in the Phase 2 tests to represent the signal levels from an AirCell mobile and determine its impact on a typical terrestrial suburban cell site. A calibrated signal generator is used to inject the representative AirCell signals into the receive paths of the terrestrial cell site, using a modulated signal as specified in the test plan.

A single terrestrial cell site is used for the Phase 2 tests. The cell site is a typical suburban site co-located by Verizon Wireless and Cingular Wireless, within the Trenton MSA market, in Mercer County, NJ. In addition, three other cell sites surrounding the

test cell site are also collocated by these carriers, or located nearby, and they have similar antenna configurations and coverage areas. The test cell site location allows for the testing of three technologies separately: AMPS, TDMA, and CDMA.

In addition, the cell site operating noise floor of the terrestrial suburban test cell site, and 18 others in the surrounding area, were measured and are provided in this report. In addition, the terrestrial test cell site received signal levels of typical customers over a 24-hour period, and the drive route used in Phase 2 tests, are provided in appendix section 9.9. In the graphs containing the terrestrial customer and drive route RSSI levels, it is observed that the drive route signal levels closely match the customer signal levels, for the suburban terrestrial test cell site used in Phase 2 tests.

In the graphs depicting the Phase 2 test results, the x-axis represents the injected signal level (simulating the interfering AirCell signal), referenced to the terrestrial cell site hatch plate, which is the same reference point in Phase 1 tests for AirCell signals received. These signal levels range from –126 to –72 dBm. (The –129 dBm point on the graph is used as a "place holder" for the baseline test, with no injected signals.) The Phase 2 tests were performed with an injected steady-state signal level starting at –126 dBm, and then, increasing at each tests iteration by 3 dB or 6 dB, to determine impact to the cell site performance for each test iteration. The y-axis represents the corresponding performance metric and is scaled accordingly (%, count, signal strength, etc.). The following sections document the significant findings for each of the technologies and the metrics.

4.1.1 Terrestrial Cellular Performance Metrics

Analysis of the Phase 2 test results allows us to determine the lowest injected signal level that causes a detectable impact to the performance of the terrestrial cell site.

For the purposes of evaluating the performance impact to the terrestrial cell site, several metrics were recorded and evaluated for the Phase 2 interference tests. Some metrics are applicable to all three technologies, while others are technology specific. Some metrics correspond to the quality of service of the calls made, and others correspond to the reverse-link cell site performance metrics. The terrestrial cellular performance metrics considered in Phase 2 testing are as follows:

- Blocked and Dropped Calls
  - These are the calls that are dropped from the system, and the attempted calls that are blocked. These are quality of service metrics, for the calls made on the drive route.
- Digital Errors Rates
  - These metrics are the error rate percentage (ie. BER% or FER%) that are measured for the cell reverse-link (mobile Tx to cell Rx). This is averaged over the entire drive route. A BER threshold is also used to show the results as a percentage of time for the drive route.

- Mean Opinion Audio Quality Score (MOS) [34]
  - This metric is the Mean Opinion Score (MOS) of the audio quality measured for the cell reverse-link, averaged over the drive route. The Comarco drive test equipment modulates specific audio conversations ("Harvard Sentences") to replicate natural speaking voice for objective assessment of the audio quality. A MOS value greater than 3.25 is considered "good" quality, and below this is considered "fair" quality. A MOS value below 2.75 is considered "poor" quality, and a MOS value below 2.25 is considered "bad" quality. The average and 90% MOS values are provided.
- Mobile Transmit Power
  - This metric is the Mobile Transmit Power for the reverse-link. This performance metric is provided as an averaged for the entire drive route.
- Call Overflow
  - This metric is for CDMA systems, and shows the percent of established calls made by the Comarco unit that are overflowed to either other CDMA carriers, or analog (AMPS) voice channels.
- Capacity
  - This metric represents the percent loss in capacity for the terrestrial test cell site, based upon the loss in MOU or loss in service available during the drive test.
- Minutes of Use (MOU)
  - This metric represents the Minutes of Use on a voice channel, for the drive test. With increased interference levels, the cellular service available for the drive route is reduced, which reduces the MOU values.
- Carrier to Interference Ratio (C/I)
  - This metric is the ratio of cell site received signal level to the interference plus noise level, for the cell site reverse link. The median and 90% levels are provided.
- Energy per Bit / Noise (Eb/No)
  - This CDMA metric is the ratio of energy of the call signal level to the noise level in the CDMA channel, for the cell site reverse-link. This is averaged over the entire drive route.

Performance Metrics: Digital Error Rates are TDMA and CDMA specific, Call Overflow is CDMA specific, Carrier to Interference (C/I) is TDMA and AMPS specific, and Eb/No and Mobile Transmit Power are for CDMA. All metrics are reported for the entire drive route.

These performance metrics were recorded for the Phase 2 interference tests performed during typical day-time business day operation under normal cell site configurations, and on the drive route within the coverage area of the suburban terrestrial test cell site.

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[34] The MOS measurement is an assessment of the audio quality of the cellular call, and it is performed with sophisticated computer algorithms at a landline phone station. It is designed to be an objective assessment of the audio quality, and yield results equivalent to a mean opinion survey of over 1,000 people. For a more detailed description of this measurement refer to the AirCell Compatibility Test Plan, provided in section 9.18 of this report.

4.2 Phase 2 Test Results – AMPS Technology Tests

The Phase 2 test results indicate performance degradations and harmful interference to the terrestrial cellular service in AMPS technology tests. The degradation is first observed with Carrier to Interference (C/I) Ratio and Mean Opinion Audio Quality Score (MOS), and then Blocked & Dropped Calls, and Minutes of Use (Capacity). These performance metrics are for the cell site reverse-link performance (mobile TX to cell RX). The performance metrics were measured during the Phase 2 drive testing, on the drive route that covers the terrestrial suburban cell site's coverage area. The Phase 2 results for AMPS technology tests are provided in the figures at the end of this section.

In the AMPS tests, a baseline drive test, with no injected interference, was performed to establish the performance of the terrestrial cell site, under normal day-time operating conditions. The performance of the baseline test establishes a reference level for other tests to be compared. During the baseline test for AMPS technology, Blocked and Dropped Calls are 0%, average MOS is 3.3, median C/I is 30 dB, 90% C/I is 20 dB, and MOU is 37.6 minutes (0% Capacity Loss) for the drive test. The median operating AMPS noise floor of the suburban test site is -127 dBm, as measured over a 24 hour period (see Appendix Section 9.9).

In the AMPS tests results with interfering signals at the -126 dBm level, there is no effect or performance degradation that is observed at the terrestrial suburban test cell site. In these tests, the performance of the terrestrial cell site is similar to the performance of the baseline test.

In the test results, the C/I performance degrades at the -123 dBm level. At this injected signal level, the median C/I is 26 dB, and the 90% C/I is 18 dB.[35] At this level, the AirCell signal would degrade the terrestrial system from the baseline (normal performance) test, and result in a reduction of C/I of 4 dB (for median) and 2 dB (for 90%). This 4 dB degradation in C/I is significant and can cause harmful interference to many cell sites within the cellular system. Many terrestrial cell sites serve customers near their minimum acceptable levels of C/I, and a 4 dB degradation in C/I will cause a reduction in call quality and dropped calls.

For the suburban terrestrial test cell site, the average MOS audio quality performance declines slightly from -120 to -117 dBm, however the MOS degrades noticeably at -114 dBm, and drops off sharply above that level. The 90% MOS declines below "good" audio quality, at an interference level of –120 dBm, to a MOS 2.5 for 10% of the MOS readings.

[35] The 90% C/I uses the 10% lowest received signal level from the drive route. This represents the level of C/I performance that can be expected 90% of the time, for all customers. The 90% C/I level is commonly used in cellular C/I and received signal strength analyses to determine acceptable levels of coverage and system performance.

At the -114 dBm injected level, the average MOS degrades by 0.2 units, below the baseline performance of MOS 3.3, to a level of MOS 3.1. (The baseline test result is represented on the graph as the -129 dBm data point.) The MOS 3.25 threshold is the minimum level for “acceptable good” quality and below this audio quality level is considered “fair” quality. At the -114 dBm injected signal level, the MOS is 3.1, the median C/I is 18 dB, and the 90% C/I is 10 dB. At this level, the voice quality of the AMPS cellular service has degraded and harmful interference is occurring.

At the –111 dBm interference level, the median C/I drops to 14 dB and 90% C/I to 5 dB. The average MOS drops to 2.8, and 10% of the readings drops below “fair” audio quality to MOS 1.9.

At the -108 dBm injected signal level, the harmful interference results in a Dropped Call percentage of 4%, and a 5% reduction in the Minutes of Use (Capacity Loss) for the drive route. At this level, the average MOS is 2.6 and 90% MOS is 1.25, the median C/I is 13 dB, and the 90% C/I is 5 dB. At this level, the harmful interference interrupts AMPS service, causes 4% of the AMPS calls to terminate abruptly (dropped calls), and results in a 5% reduction in usage.

In conclusion, the Phase 2 test results indicate performance degradations and harmful interference to terrestrial cellular service in AMPS technology tests. At levels from -123 dBm to -117 dBm, the harmful interference degrades the performance of terrestrial AMPS cellular service for cell sites and calls operating at their minimum performance levels. At these levels, the harmful interference is expected to occur at terrestrial cell sites with larger coverage radius than the suburban test site, which are serving terrestrial mobiles at lower signal levels. In addition, this is expected to cause harmful interference to terrestrial in-building cellular calls, which operate at lower signal levels due to the signal path attenuation of the building structure. This effect is particularly significant, as the trend for terrestrial cellular phone use in-buildings is increasing.

At the level of -114 dBm, the harmful interference degraded the performance of AMPS cellular service provided by the suburban test cell site. The test cell site is a typical suburban cell site, which has a coverage radius of 1.5 miles. Terrestrial cell sites with larger coverage areas, or those serving in-building calls, can expect greater signal path loss, lower received signal levels, and harmful interference that occurs with interfering signals at lower levels than the test cell site. In these cases, harmful interference to AMPS cellular service is expected to occur below the -114 dBm level, and within the -117 to -123 dBm range.

The AMPS terrestrial test cell site’s operating noise floor was measured over a 24 hour period and is provided in Appendix Section 9.9. The AMPS cell site’s median operating noise floor is -127 dBm. With this noise floor level, AMPS cellular calls can operate at -110 dBm, with “toll quality” (17 dB C/I). Any outside-system interference that is received above -127 dBm has the potential to cause interference to AMPS terrestrial cellular calls operating at the -110 dB level.

In addition, V-COMM conducted similar noise floor measurements at 18 other AMPS terrestrial cell sites across the NJ, and Philadelphia, PA cellular market area. Included are 5 sites in rural areas, 5 sites in suburban areas, 5 sites in urban areas, and 3 sites in dense urban areas. Of the 18 cell sites tested, 13 cell sites had a median operating noise floor level of -127 dBm, similar to the AMPS terrestrial cell site used in Phase 2 tests. These results are provided in the AMPS Noise Floor Study, provided in Appendix Section 9.17.

Figure 4.2-A Phase 2 Test Results: AMPS Median Carrier to Interference Ratio

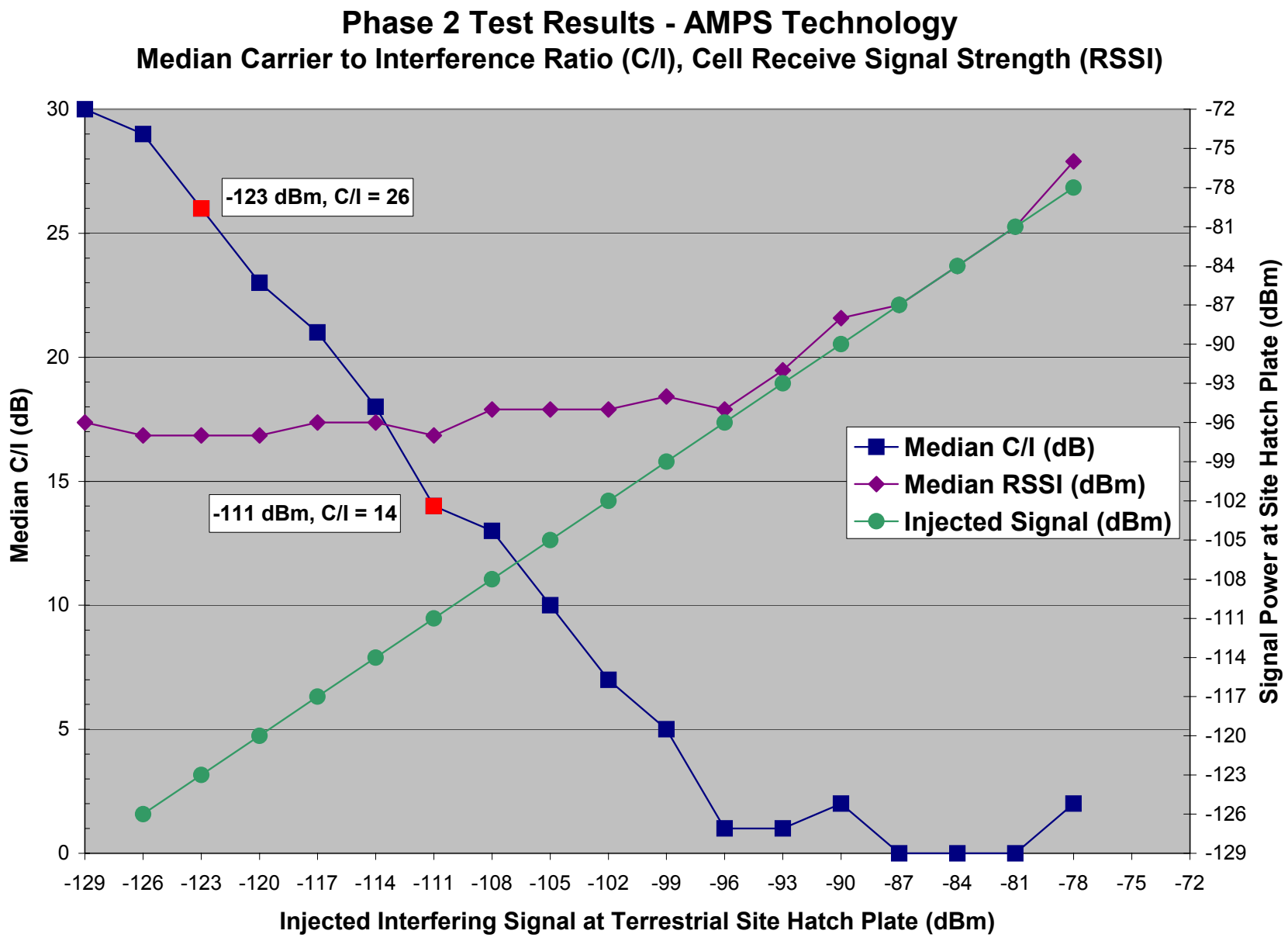


Figure 4.2-B Phase 2 Test Results: AMPS 90% Carrier to Interference Ratio

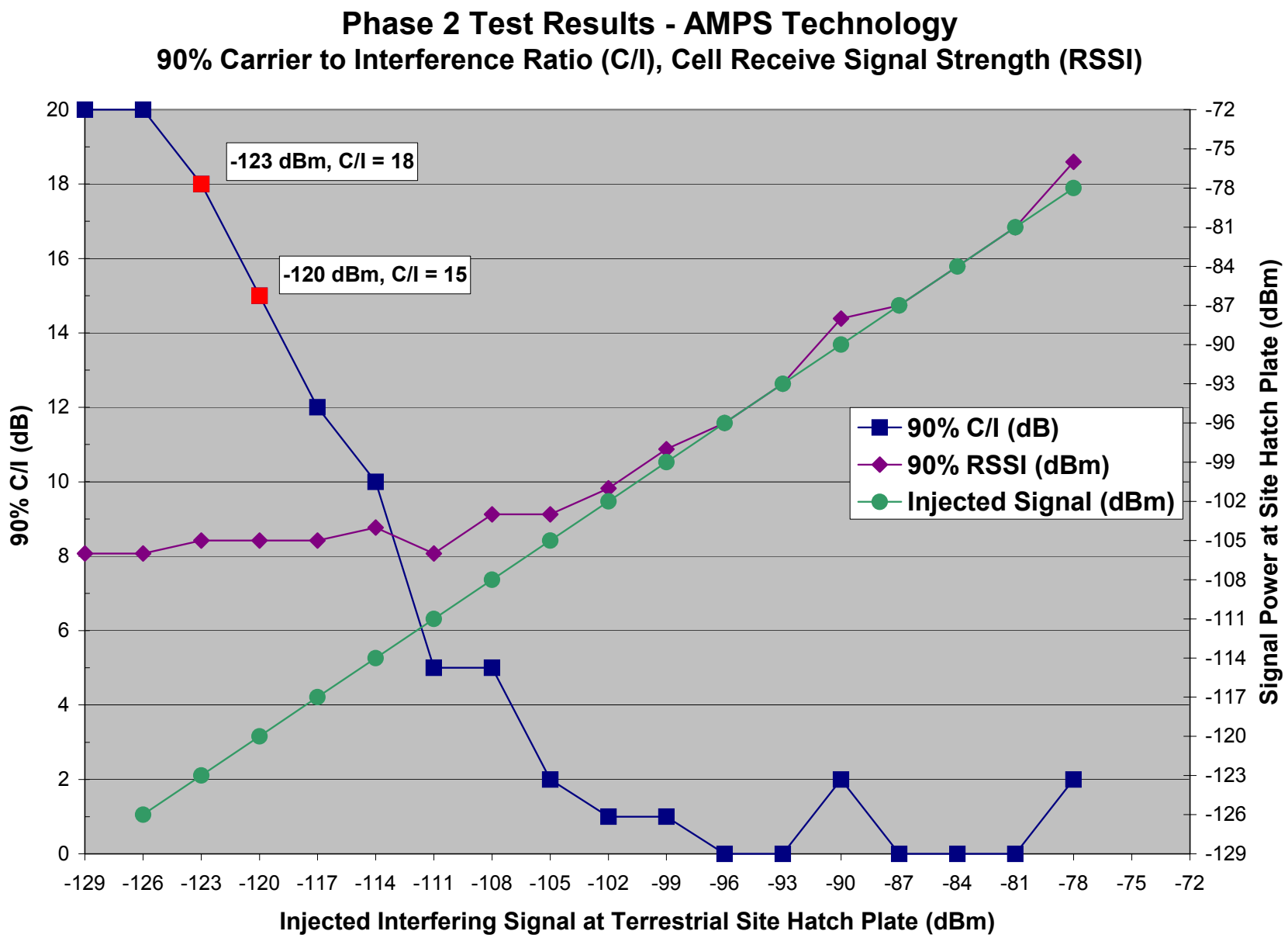


Figure 4.2-C Phase 2 Test Results: AMPS Mean Opinion Audio Quality Score

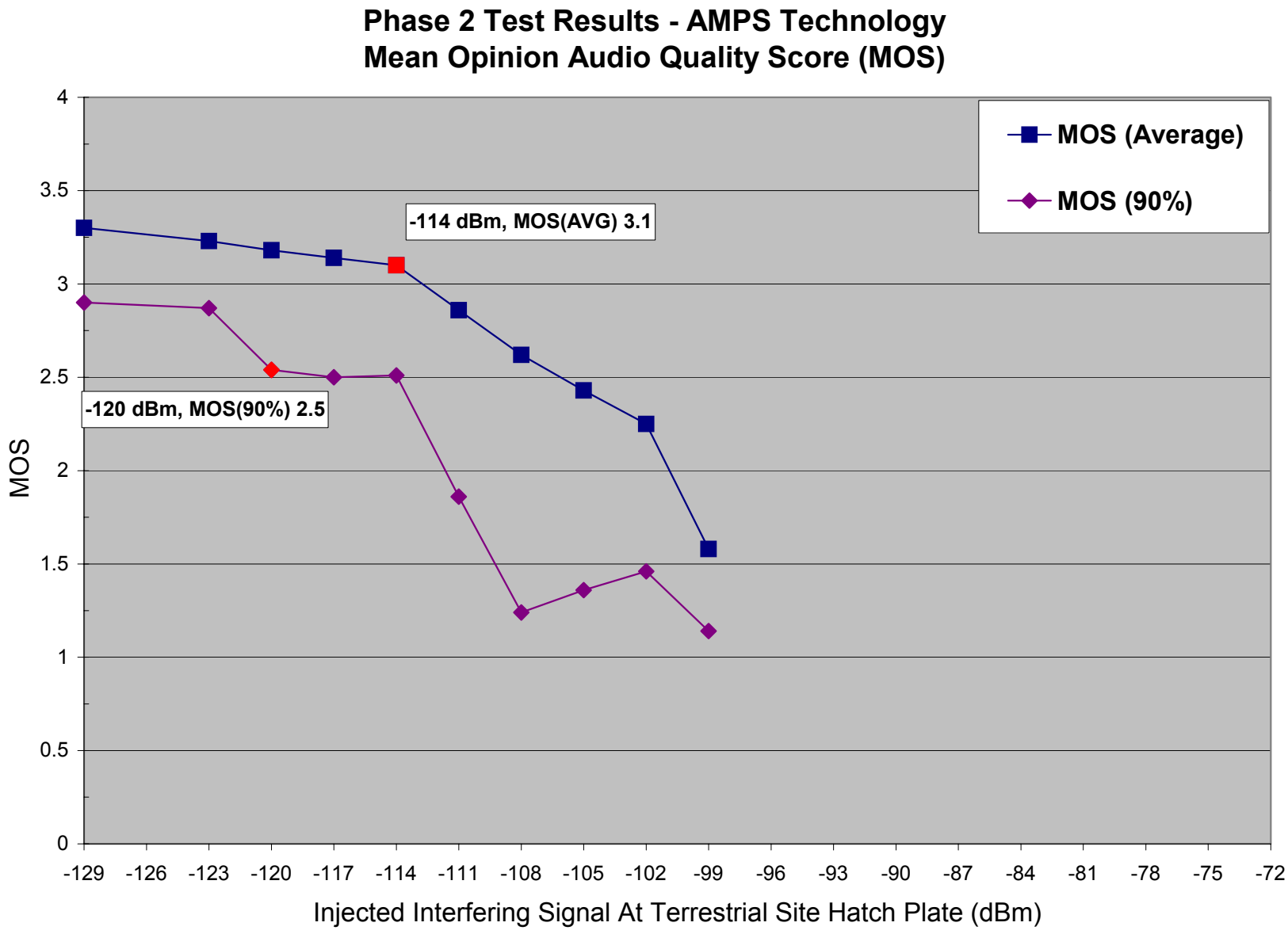


Figure 4.2-D Phase 2 Test Results: AMPS Blocked and Dropped Call Percentage

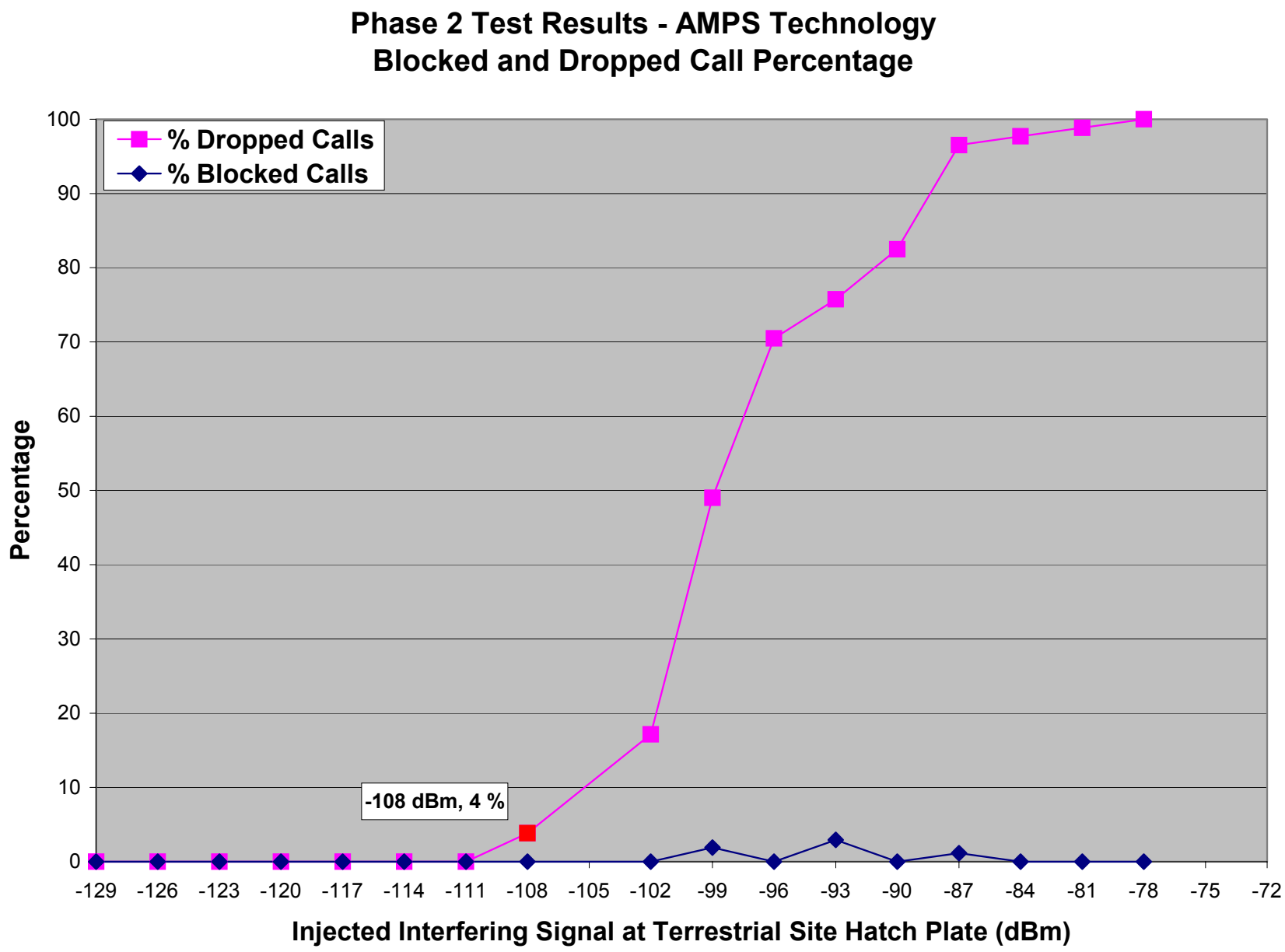
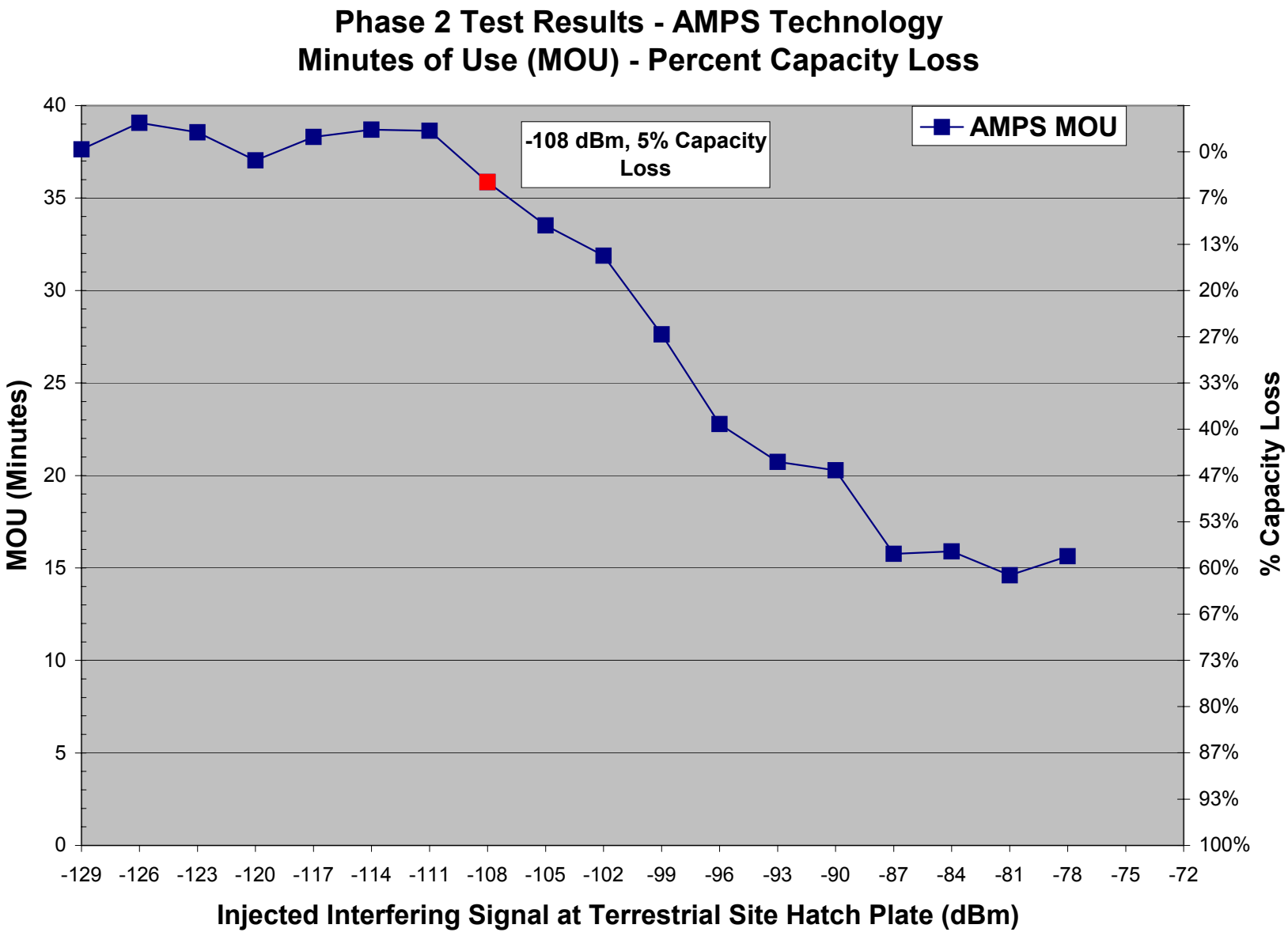


Figure 4.2-E Phase 2 Test Results: AMPS Minutes of Use



4.3 Phase 2 Test Results – TDMA Technology Tests

The Phase 2 test results indicate performance degradations and harmful interference to the terrestrial cellular service in TDMA technology tests. The degradation is first observed with Carrier to Interference (C/I) Ratio, and then in Dropped Calls, Bit Error Rate (BER), Mean Opinion Audio Quality Score (MOS), and Minutes of Use (MOU). The C/I, BER and MOS performance metrics are for the cell site reverse-link (mobile TX to cell RX). The performance metrics were measured during the Phase 2 drive testing, on the drive route that covers the terrestrial suburban cell site's coverage area. The Phase 2 results for TDMA technology tests are provided in the figures at the end of this section.

In the TDMA tests, a baseline drive test, with no injected interference, was performed to establish the performance of the terrestrial cell site, under normal day-time operating conditions. The performance of the baseline test establishes a reference level for other tests to be compared. During the baseline test for TDMA technology, Blocked and Dropped Calls are 0%, average MOS is 3.6, average BER is 0.1%, median C/I is 25 dB, 90% C/I is 15 dB, and MOU is 35.9 minutes (0% Capacity Loss) for the drive test. The median operating TDMA noise floor of the suburban test site is -127 dBm, as measured over a 24 hour period (see Figure 9.9-B).

In the TDMA tests results with interfering signal levels in the range of -126 to -123 dBm, there is no effect or performance degradation that is observed at the terrestrial suburban test cell site. In these tests, the performance of the terrestrial cell site is similar to the performance of the baseline test.

In the test results the C/I performance degrades at the -120 dBm level. At this injected signal level, the median C/I is 22 dB, and the 90% C/I is 13 dB.[36] At this level, the AirCell signal would degrade the terrestrial system from the baseline (normal performance) test, and result in a reduction of C/I of 3 dB (for median) and 2 dB (for 90%). This 3 dB degradation in C/I is significant and can cause harmful interference to many cell sites within the cellular system. Many terrestrial cell sites serve customers near their minimum acceptable levels of C/I, and a 3 dB degradation in C/I will cause a reduction in call quality and dropped calls.

For the suburban terrestrial test cell site, the TDMA BER performance begins to degrade at the injected signal level of -117 dBm. The test results indicate a 0.5% increase in BER at -117 dBm, a 1% increase in BER at -114 dBm, over the baseline test with no injected signals. At -117 dBm, the BER is 0.7%, at -114 dBm the BER is 1.2%, and at -111 dBm the BER is 2%. The 0.5% and 1% increase in TDMA BER (at -117 and -114 dBm levels) is significant and can cause harmful interference to many cell

[36] The 90% C/I uses the 10% lowest received signal level from the drive route. This represents the level of C/I performance that can be expected 90% of the time, for all customers. The 90% C/I level is commonly used in cellular C/I and received signal strength analyses to determine acceptable levels of coverage and system performance.

sites within the cellular system. Many terrestrial cell sites serve customers near their minimum acceptable levels of BER, and this performance degradation will cause a reduction in call quality. Also, at the –117 dBm level, the percentage of service below 1% BER threshold drops by 18%, from the base line test.

At the -114 dBm injected signal level, the harmful interference results in a Blocked Call percentage of 4%, and a 7.3% reduction in Minutes of Use (Capacity Loss) for the drive route. At this level, the median C/I is 15 dB, the 90% C/I is 7 dB, the average BER is 1.2%, 25% of BER readings are greater than 1% BER, and the average MOS is 3.3, and the 90% MOS is 2.6. At this level, the average MOS degrades by 0.3 units, below the previous tests at lower injected signal levels. At this level, the harmful interference causes serious obstructions to TDMA service; causing 4% of the TDMA call attempts to fail, and results in a 7.3% reduction in usage.

At the -111 dBm injected signal level, the harmful interference results in a Blocked Call percentage of 7.4%, and a 7.5% reduction in Minutes of Use (Capacity Loss) for the drive route. At this level, the median C/I is 14 dB, the 90% C/I is 6 dB, the average BER is 2%, 32% of BER readings are greater than 1% BER, the average MOS is 3.2, and the 90% MOS is 1.2. At this level, the average MOS has degraded below the minimum level for acceptable “good” quality audio. At this level, the harmful interference causes serious obstructions and degradations to TDMA service; causing 7.4% of the TDMA call attempts to fail, degraded voice quality, and results in a 7.5% reduction in usage.

At the -108 dBm injected signal level, the harmful interference results in a Blocked Call percentage of 28%, a Dropped Call percentage of 50%, a 30% reduction in Minutes of Use (Capacity Loss) for the drive route, and the percentage of service below 1% BER threshold drops by 43%, from the base line test. Although the average MOS results for the -108 dBm point appears out of trend, this is due to the amount of Blocked and Dropped Calls that are occurring at this level, which has the effect of preventing calls in poor signal areas of the drive route. At this level, there is a significant loss of coverage area that no longer serves the test mobile. The calls only go through when the test mobile is closer to the cell site, and the path loss is less. At injected signals levels above the -108 dBm level, the Dropped Calls begin to taper off due to the fact that the number of calls being blocked are increasing and thus the opportunity to drop the call is not occurring. The baseline test results with no injected signals has a performance of 0% Blocked Calls and 0% Dropped Calls. Above the -105 dBm injected signal level, the test equipment has difficulty computing the MOS values as the interference causes significant deterioration in audio quality.

In conclusion, the Phase 2 test results indicate performance degradations and harmful interference to terrestrial cellular service in TDMA technology tests. At levels of -120 dBm to -117 dBm, the harmful interference degrades the performance of terrestrial TDMA cellular service for cell sites and calls operating at their minimum performance levels. At levels of -120 dBm to -117 dBm, the harmful interference is expected to occur at terrestrial cell sites with larger coverage radius than the suburban test site, which are serving terrestrial mobiles at lower signal levels. In addition, this is expected to cause

harmful interference to terrestrial in-building cellular calls, which operate at lower signal levels due to the signal path attenuation of the building structure. This effect is particularly significant, as the trend for terrestrial cellular phone use in-buildings is increasing.

At levels of -114 dBm, the harmful interference causes serious obstructions and degradations to TDMA cellular service provided by the suburban test cell site. The test cell site is a typical suburban cell site, which has a coverage radius of 1.5 miles. Terrestrial cell sites with larger coverage areas, or those serving calls in-buildings, can expect greater signal path loss, lower received signal levels, and harmful interference that occurs with interfering signals at lower levels than the test cell site. In these cases, harmful interference to TDMA cellular service is expected to occur below the -114 dBm level, and within the -117 to -120 dBm range.

In cases of harmful interference to TDMA digital control channels, the effects are worse. In addition to affecting two timeslots carrying voice traffic, harmful interference to the digital control channel can block all new calls on the cell site sector. For TDMA subscribers in the area, this can result in the inability to make calls within this sector, including all calls made to 911 and other emergency telephone calls.

In cases of harmful interference to TDMA voice channels, the interference can affect up to 3 calls at a time. TDMA cellular systems utilize 3 timeslots on each radio channel. TDMA system operators assign voice channels and digital control channels for each cell site and sector. TDMA radio channels assigned with only voice channels have three timeslots for voice traffic. TDMA radio channels assigned with digital control channels have one timeslot for the digital control channel, and two for voice traffic.

The TDMA terrestrial test cell site's operating noise floor was measured over a 24 hour period and is provided in Appendix Section 9.9. The TDMA cell site's median operating noise floor is -127 dBm. With this noise floor level, TDMA cellular calls can operate at -110 dBm, with "toll quality" (17 dB C/I). Any outside-system interference that is received above -127 dBm has the potential to cause interference to terrestrial TDMA cellular calls operating at the -110 dB level.

Figure 4.3-A Phase 2 Test Results: TDMA Median Carrier to Interference Ratio

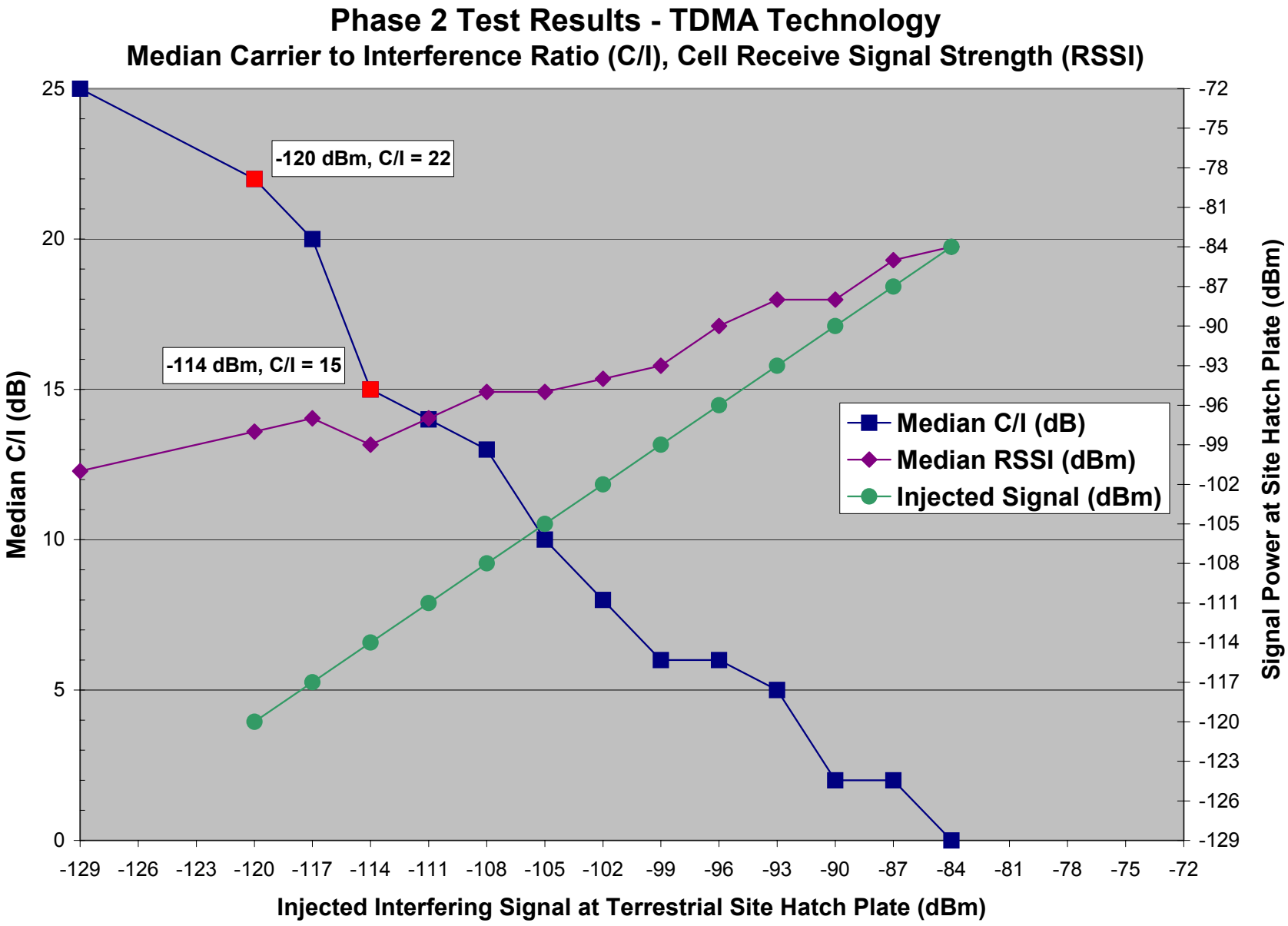


Figure 4.3-B Phase 2 Test Results: TDMA 90% Carrier to Interference Ratio

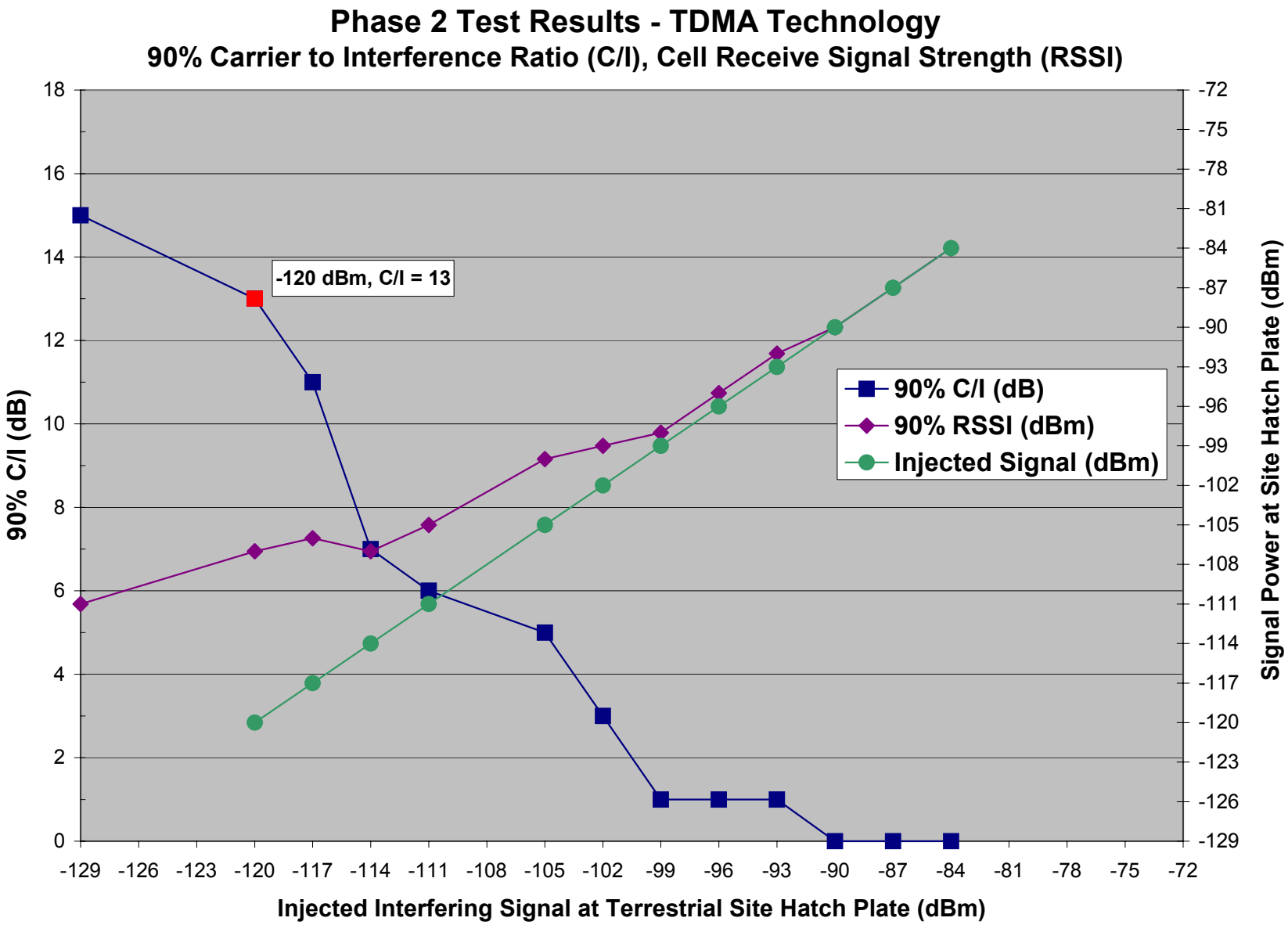


Figure 4.3-C Phase 2 Test Results: TDMA Bit Error Rate Percentage

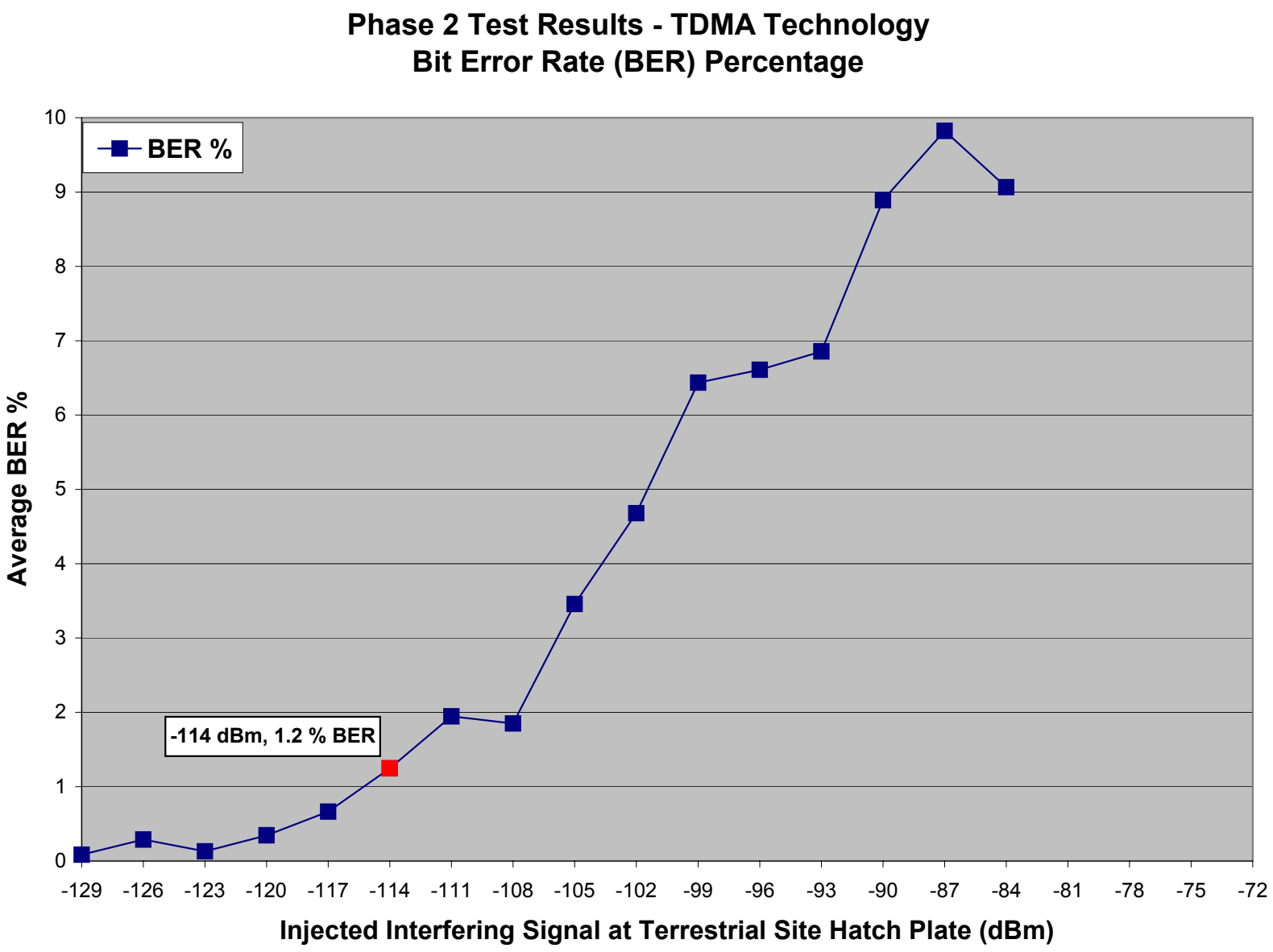


Figure 4.3-D Phase 2 Test Results: TDMA Bit Error Rate - Percentage of Time below BER Threshold

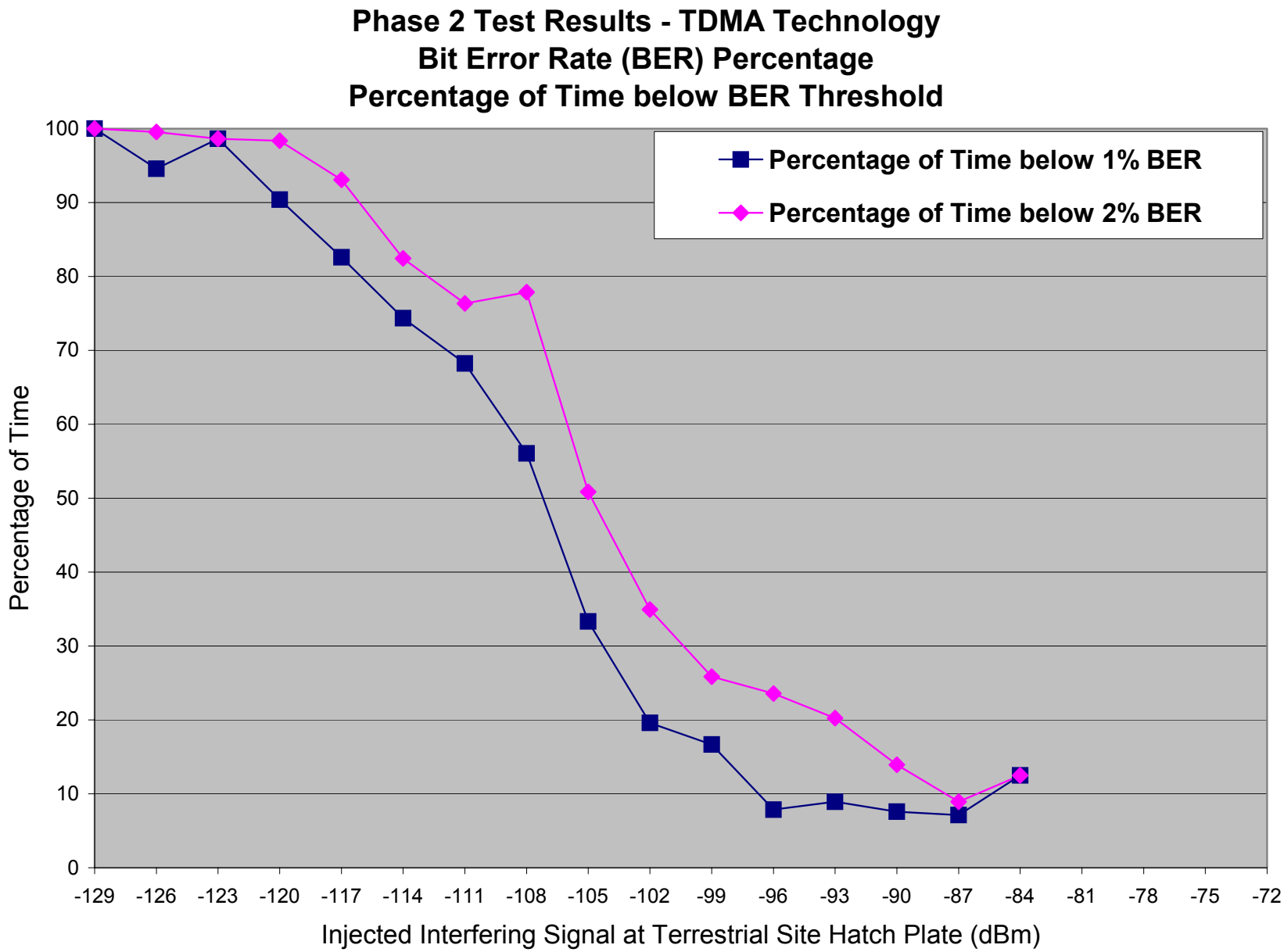


Figure 4.3-E Phase 2 Test Results: TDMA Mean Opinion Audio Quality Score

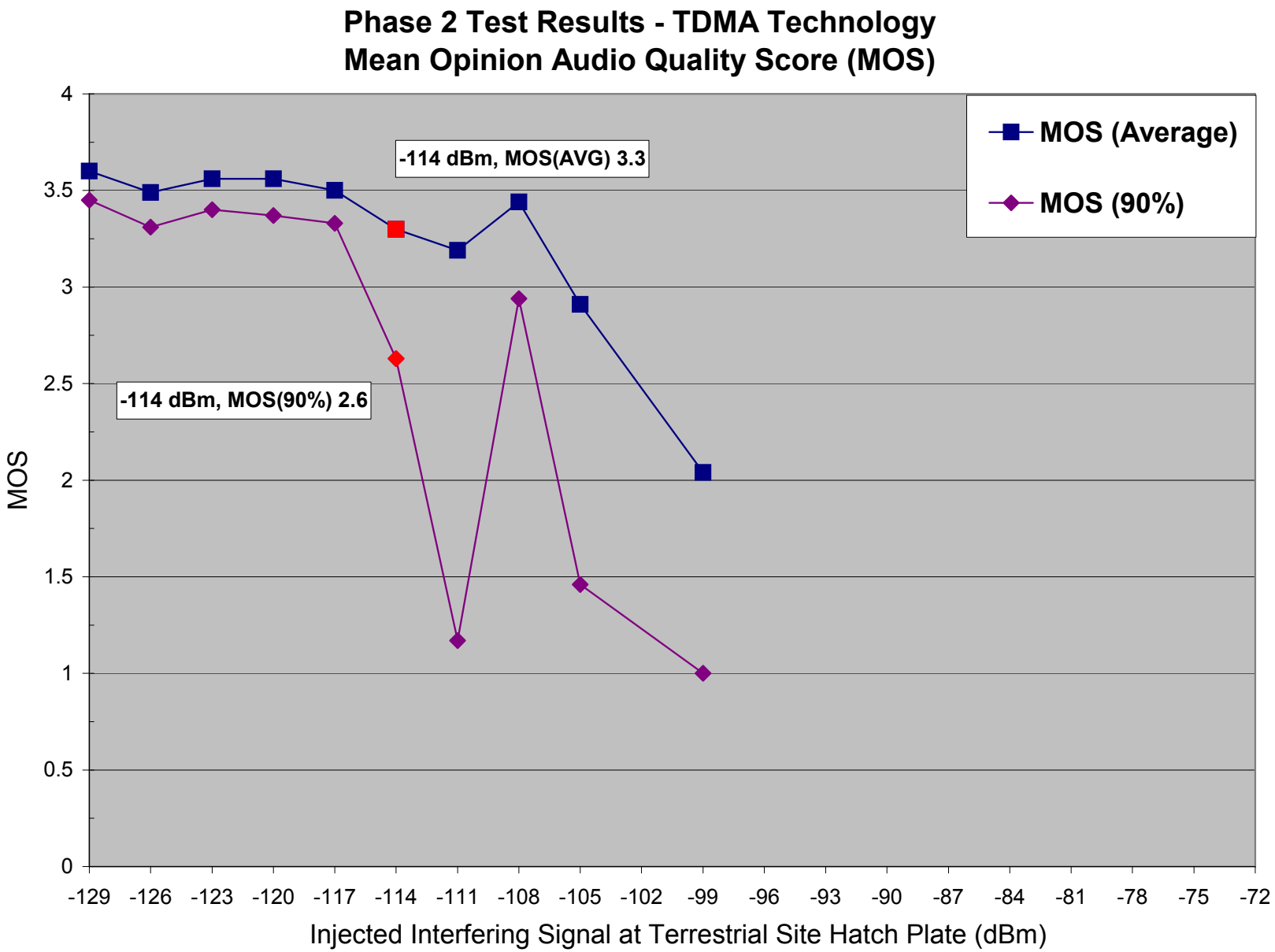


Figure 4.3-F Phase 2 Test Results: TDMA Blocked and Dropped Call Percentage

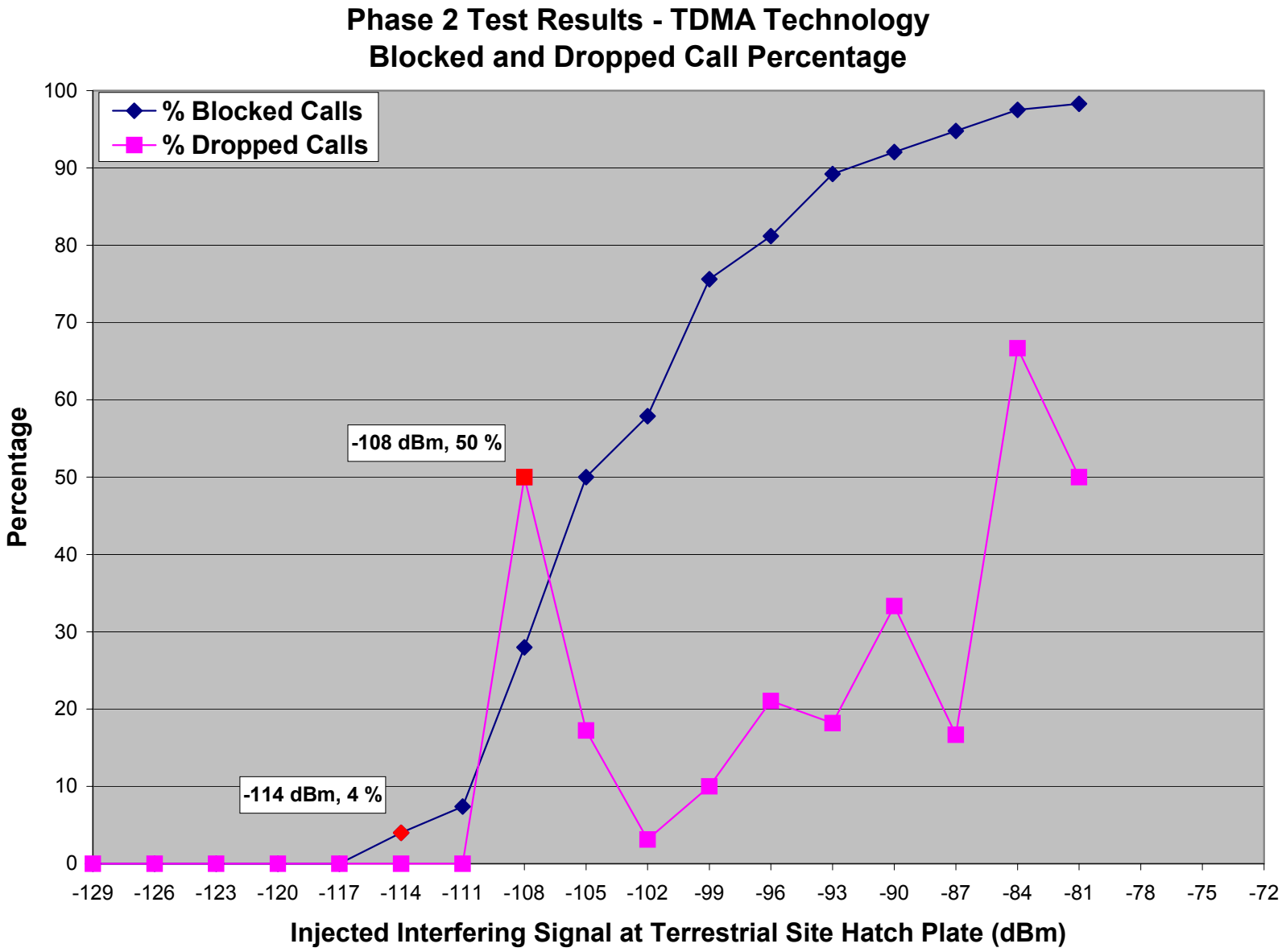
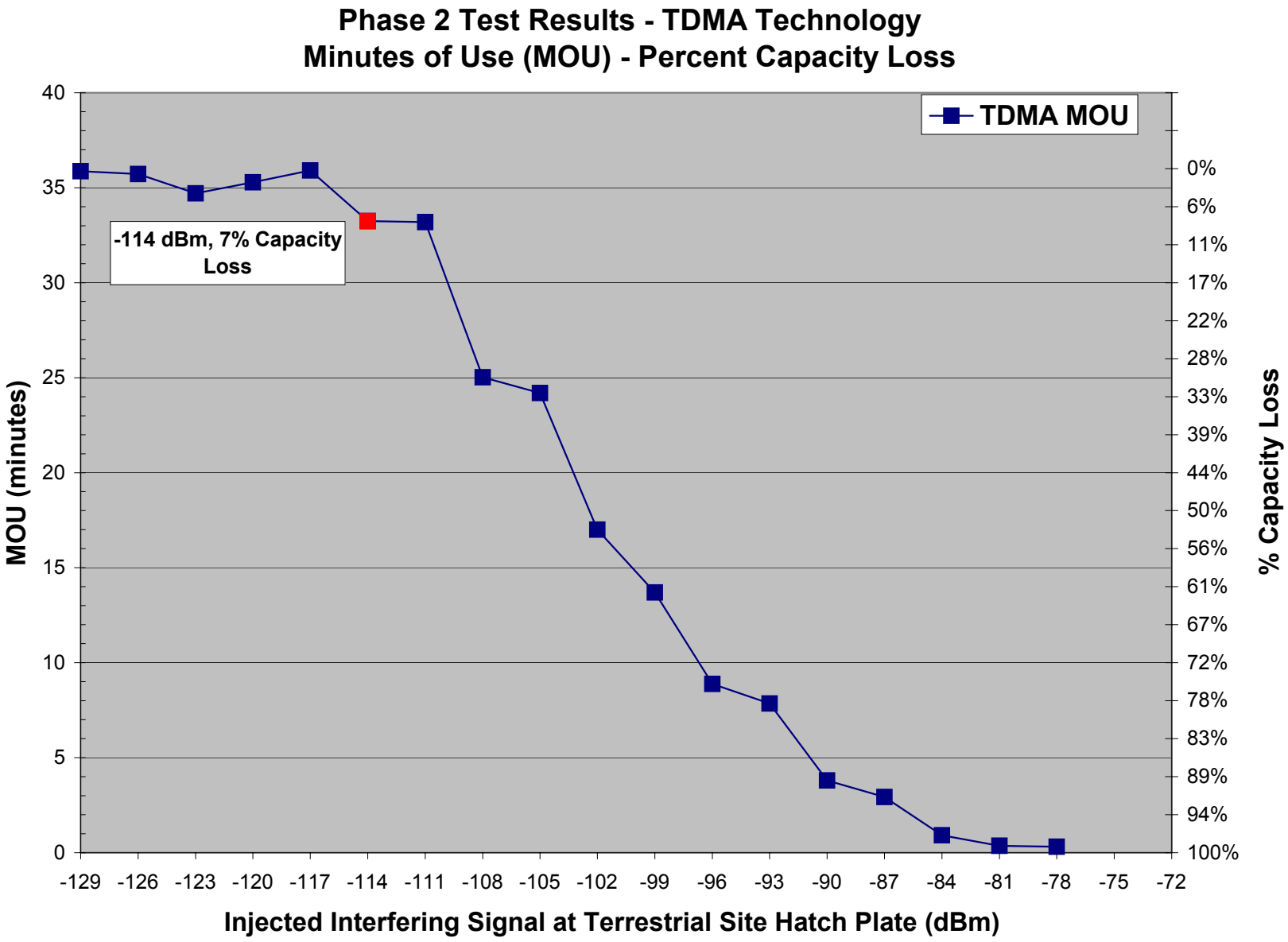


Figure 4.3-G Phase 2 Test Results: TDMA Minutes of Use



4.4 Phase 2 Test Results – CDMA Technology Tests

The Phase 2 test results indicate performance degradations and harmful interference to the terrestrial cellular service in CDMA technology tests. The performance impact is first observed in terrestrial Mobile Transmit Power, then Blocked, Dropped and Overflowed Calls, Minutes of Use (MOU), Mean Opinion Audio Quality Score (MOS),[37] and Bit Energy per Noise (EbNo). The Mobile Transmit Power, MOS and EbNo performance metrics are for the cell site reverse-link (mobile TX to cell RX). The performance metrics were measured during the Phase 2 drive testing, on the drive route that covers the terrestrial suburban cell site's coverage area. The Phase 2 results for CDMA technology tests are provided in the figures at the end of this section, and in Appendix Sections 9.10 to 9.14.

In the CDMA tests, a baseline drive test, with no injected interference, was performed to establish the performance of the terrestrial cell site, under normal day-time operating conditions. The performance of the baseline test establishes a reference level for other tests to be compared. During the baseline test for CDMA technology, Blocked and Dropped Calls are 0%, Overflowed Calls are 0%, Eb/No is 6.8 dB, and MOU is 35.8 minutes (0% Capacity Loss) for the drive test. The reference level for CDMA Mobile Transmit Power is 7.3 dBm, with the mobile transmit power in the range from 6.7 dBm (for the baseline test) to 7.3 dBm (for the test at –126 dBm injection).

In the CDMA drive tests during normal day-time loading conditions, in tests with injected signals on the CDMA carrier, there is no effect or performance degradation that is observed at the terrestrial suburban test cell site, with injected interfering signals in the range of -126 to -123 dBm. In these tests, the performance of the terrestrial cell site is similar to the performance of the baseline test.

In the CDMA drive tests during normal day-time loading conditions, in tests with 1 injected signal on the CDMA carrier, a 1.6 dB increase in Mobile Transmit Power occurs at the -120 dBm interfering level, and a 3.1 dB increase in Mobile Transmit Power occurs at -114 dBm. These increases in mobile transmit power are over the range of levels observed in the two previous tests at lower injected signal levels, and the baseline test, with no injected interference. At the -120 dBm level, the AirCell signal would degrade the performance of the terrestrial CDMA system from its normal operation, and result in an increased operating noise floor. In CDMA systems, increases in the operating noise floors is harmful interference, which causes a reduction in system coverage, capacity and quality of terrestrial calls served by the CDMA carrier.

Harmful interference to a CDMA carrier on a CDMA cell site sector can affect as many as 20 calls simultaneously, and other calls supported in soft handoff modes. In addition, since CDMA systems utilize the same frequency in all sectors and cell sites within its

[37] The Mean Opinion Score measurements were not collected for all drive tests with CDMA technology due to inadvertent test equipment collection issues.

network, the harmful interference can be received at the surrounding sectors and cell sites, as well. This can have a compounding effect of increasing operating noise floors of the CDMA cell sites, with all terrestrial mobile transmitters compensating and increasing power, which in turn further increases the operating noise floor. With the increasing noise floor in the surrounding area, all sectors in the area will experience the effects of the interference, regardless of their antenna azimuth orientation to the airborne AirCell mobile.

In CDMA systems, small increases in operating noise floors can have dramatic effects, degrading the performance of the CDMA cellular network and its ability to provide coverage, capacity, and acceptable call quality levels. At the -120 dBm interfering level, the 1.6 dB increase in mobile transmit power is significant and will cause harmful interference to many cell sites within the terrestrial cellular network; causing increased operating cell site noise floors, degradation in call quality, and dropped calls.

In the CDMA drive tests at the 3 dB system loading condition,[38] in tests with 1 injected signal on the CDMA carrier, harmful interference was observed for the suburban terrestrial test cell site. At the -111 dBm interfering signal level, the harmful interference results in a Blocked Call percentage of 11%, and a 4.8 dB increase in mobile transmit power and cell site operating noise floor. At the -108 dBm injected signal level, the harmful interference results in a Blocked Call percentage of 33.3%, and a 33.4% reduction in the Minutes of Use (Capacity Loss).

In conclusion, the Phase 2 test results indicate performance degradations and harmful interference to the terrestrial cellular service in CDMA technology tests. At the -120 dBm level, the harmful interference degrades the performance of terrestrial CDMA cellular service by raising its operating noise floor. For CDMA cell sites, this translates to reduced coverage, capacity and call quality. At this level, the harmful interference is expected with terrestrial cell sites in suburban, rural, and quiet rural markets with larger coverage radius and mobiles operating at higher transmit power levels, than the suburban test site. In addition, this is expected to cause harmful interference to terrestrial in-building cellular calls, which operate at higher mobile transmit power levels due to the increased signal path attenuation of the building structure. This effect is particularly significant, as the trend for terrestrial cellular phone use in-buildings is increasing.

At the -111 dBm level, a single injected signal on the carrier causes harmful interference that seriously obstructs and degrades CDMA cellular service provided by the suburban test cell site. The test cell site is a typical suburban cell site, which has a coverage radius of 1.5 miles. Terrestrial cell sites with larger coverage areas, or those serving calls in-buildings, can expect greater signal path loss, higher mobile transmit power levels, and harmful interference that occurs with interfering signals at lower levels than the test cell site. In these cases, harmful interference to CDMA terrestrial cellular

[38] The CDMA tests at 3 dB loading simulate the typical system noise floor level that occurs during system busy hours of the cellular system.

service is expected to occur below the -111 dBm level, and within the -114 to -120 dBm range.

Figure 4.4-A Phase 2 Test Results: CDMA Mobile Transmit Power, 1 Injected Signal on Carrier

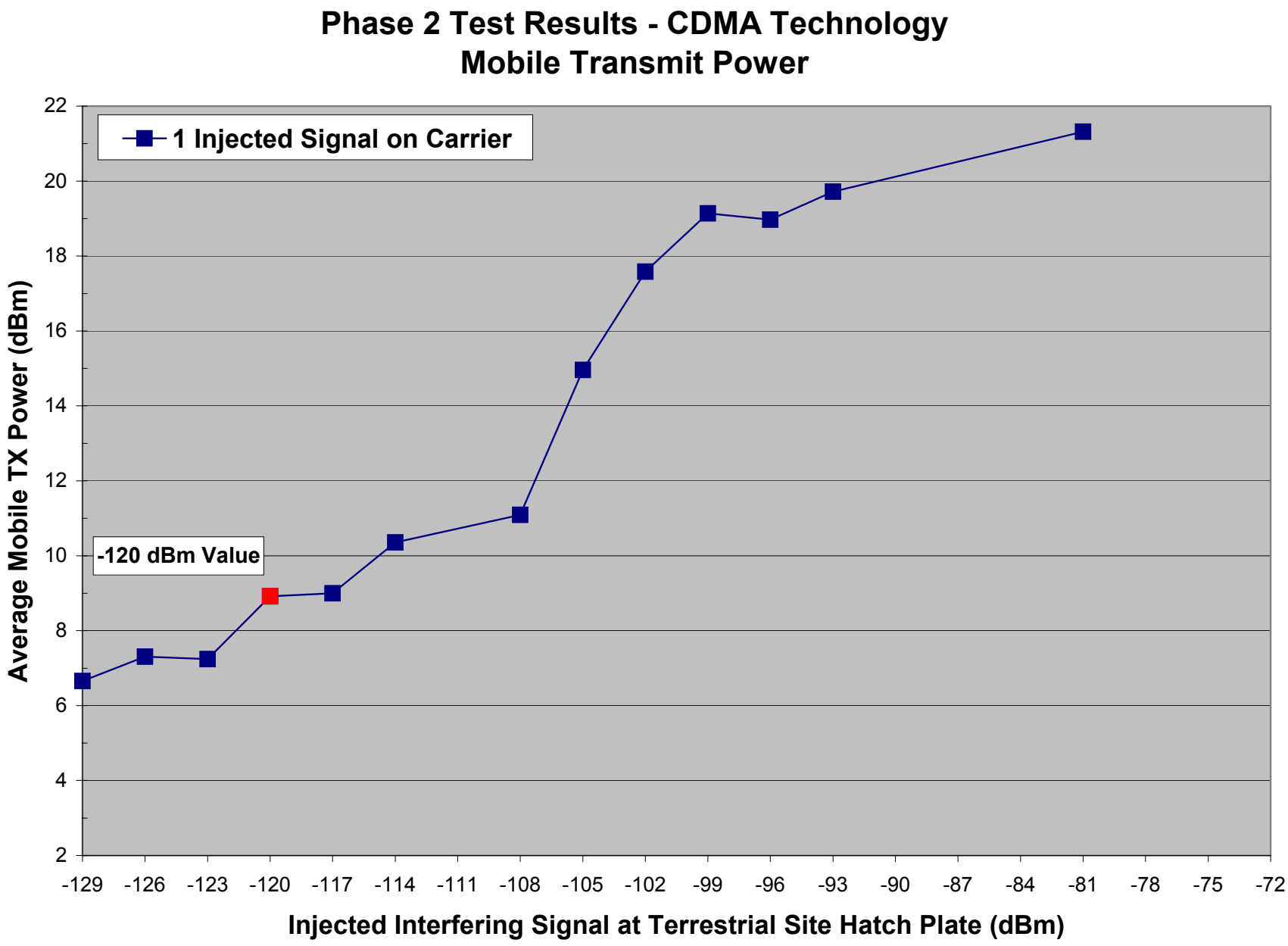


Figure 4.4-B Phase 2 Test Results: CDMA Blocks, Drops, and Overflow, 1 Injected Signal on Carrier, 3 dB Loading

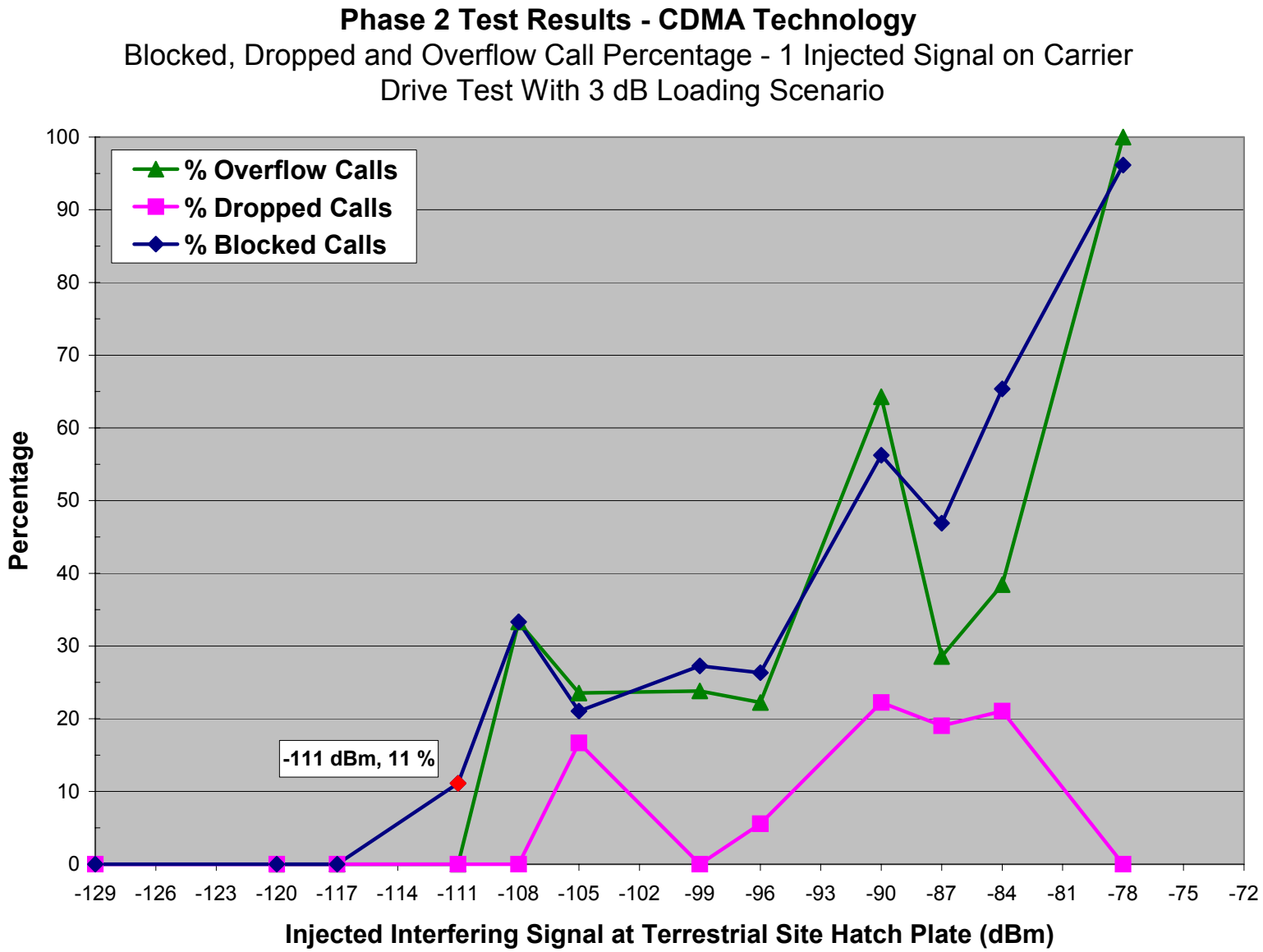
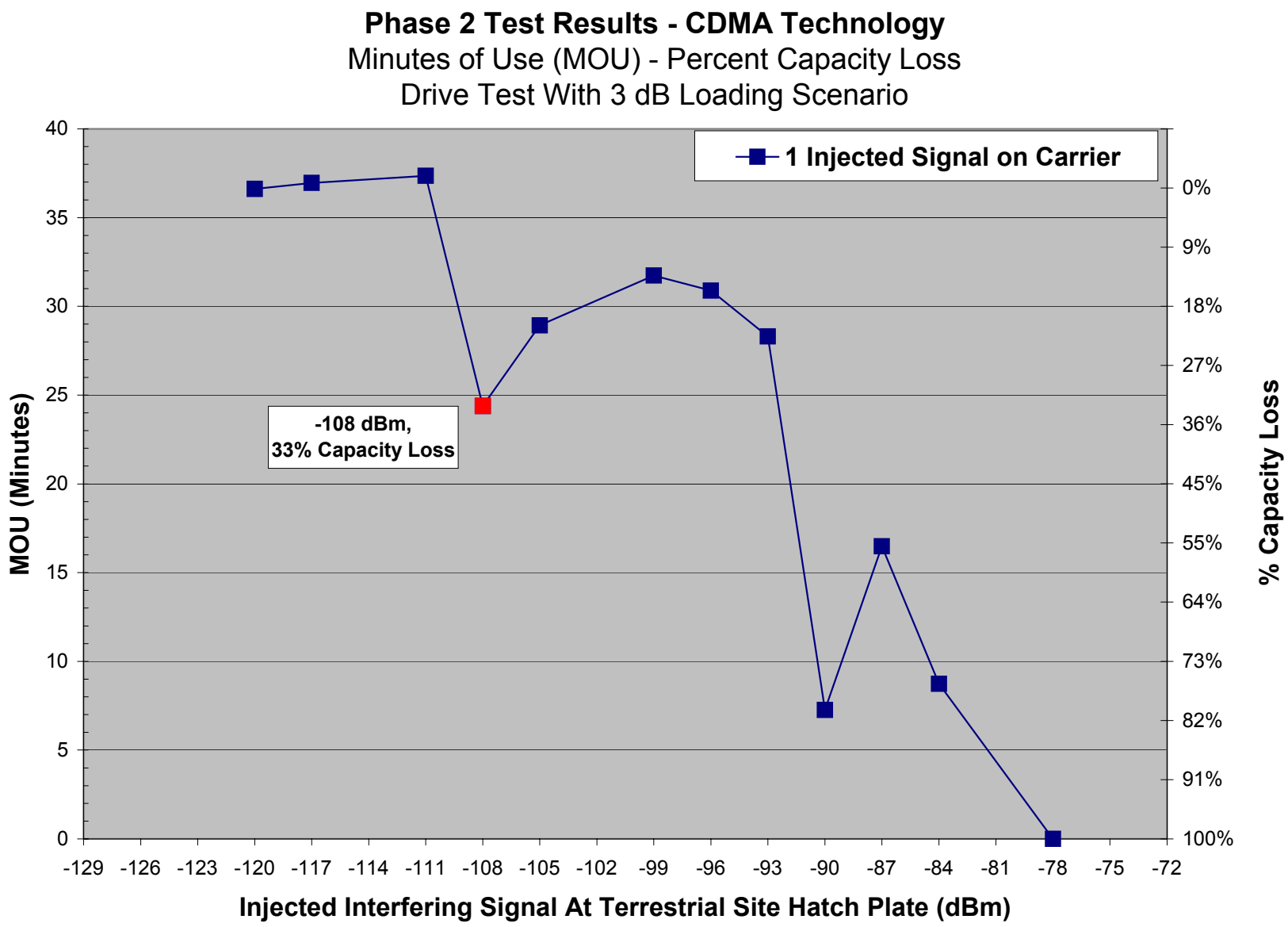


Figure 4.4-C Phase 2 Test Results: CDMA Minutes of Use, 1 Injected Signal on Carrier, 3 dB Loading



4.5 Summary of Phase 2 Tests Results

A summary of the results of the Phase 2 tests are provided in Table 4.5-A (below), for terrestrial AMPS, TDMA and CDMA systems. “No effect” to the performance of the terrestrial cellular system is observed in tests with injected interfering signals of –126 dBm for AMPS, and –123 dBm for CDMA and TDMA. However, in tests at higher injected interfering signal levels, the results indicate harmful interference to terrestrial cellular service.

Performance degradations and harmful interference to the terrestrial cellular system is observed, in tests beginning at the injected interfering signal level of –123 dBm for AMPS cellular systems, and –120 dBm for TDMA and CDMA cellular systems. As indicated in the test results, the harmful interference causes a 4 dB decrease in AMPS C/I, a 3 dB decrease in TDMA C/I, and a 1.6 dB increase in CDMA Mobile transmit Power. In terrestrial cellular systems, the performance of these metrics are directly related to the performance and quality of service provided by the cellular system.

In CDMA tests, with equivalent AirCell signals as low as -120 dBm, a 1.6 dB increase in Mobile Transmit Power was observed at the terrestrial suburban test site. In addition, when equivalent AirCell signals are received at the -114 dBm level, greater than a 3 dB increase in Mobile Transmit Power was measured. These results are for CDMA tests with 1 injected signal on the CDMA carrier channel, during tests with normal cell site configuration and day-time operation. Increases in CDMA mobile transmit power is due to the increased operating cell site noise floor, which is caused by the injected AirCell signals. This represents harmful interference, and will cause a reduction of coverage, capacity and call quality for many terrestrial CDMA cell sites and calls. It should be noted that “larger” suburban cells, as well as rural and quiet rural cells can expect to see significant impact at the -120 dBm level, since they serve customers with increased path loss and at higher mobile transmit power levels. The same is also true for in-building users within the cell’s coverage footprint, and users at the cell edge.

In TDMA tests, a reduction in C/I was measured with equivalent AirCell signals as low as -120 dBm, with increases in BER in the range of -120 to -117 dBm, and decreases in MOS at signal levels in the -114 dBm range, for the terrestrial suburban test site. It should be noted that “larger” suburban cells, as well as rural and quiet rural cells can expect to see significant impact at the lower end of the range, i.e. closer to -120 dBm, since they serve customers with increased path loss and receive signals at lower levels. The same is also true for in-building users within the cell’s coverage footprint, and users at the cell edge.

In AMPS tests, A reduction in C/I was measured with equivalent AirCell signals as low as -123 dBm, with significant decreases in MOS at signal levels in the -114 dBm range, for the terrestrial suburban test site. It should be noted that “larger” suburban cells, as well as rural and quiet rural cells can expect to see significant impact at the lower end of the range, i.e. closer to -123 dBm, since they serve customers with increased path loss

and receive signals at lower levels. The same is also true for in-building users within the cell's coverage footprint, and users at the cell edge.

In other tests under Phase 2 of the AirCell Compatibility Tests, the AMPS and TDMA terrestrial test cell sites' operating noise floor was measured at -127 dBm. In addition, thirteen other AMPS terrestrial cell sites, in dense urban, urban, suburban and rural markets within the surrounding area, were measured to -127 dBm, as well.[39] With these noise floor levels, terrestrial cellular calls can operate at -110 dBm, with "toll quality" (17 dB C/I). Any outside-system interference that is received above -127 dBm has the potential to cause interference to terrestrial cell sites and calls operating at the -110 dB level.

A summary of the Phase 2 test results, for each wireless technology included in the testing, is provided in Table 4.5-A below.[40]

[39] For additional information regarding these measurements, refer to the AMPS Noise Floor Study in appendix section 9.17.

[40] In Table 4.5-A, the Phase 2 test results provided for CDMA technology are from tests with 1 injected signal on the CDMA carrier channel.

Table 4.5-A Phase 2 Test Results – Summary Results Table

Injected Interfering Signal Level	AMPS Tests – Effects to System Performance	TDMA Tests – Effects to System Performance	CDMA Tests – Effects to System Performance
Baseline, with no injected interference	Reference Level	Reference Level	Reference Level
-126 dBm	"No effect"	"No effect"	"No effect"
-123 dBm	C/I 4 dB dec.	"No effect"	"No effect"
-120 dBm	C/I 7 dB dec. MOS 0.1 dec.	C/I 3 dB dec. BER 0.2% inc.	Tx Pwr 1.6 dB inc.
-117 dBm	C/I 9 dB dec. MOS 0.2 dec.	C/I 5 dB dec. BER 0.5% inc.	Tx Pwr 1.7 dB inc.
-114 dBm	C/I 12 dB dec. MOS 0.2 dec.	C/I 10 dB dec. BER 1.1% inc. MOS 0.3 dec. Blocked Calls 4% Capacity Loss 7%	Tx Pwr 3.1 dB inc.
-111 dBm	C/I 16 dB dec. MOS 0.4 dec.	C/I 11 dB dec. BER 1.8% inc. MOS 0.4 dec. Blocked Calls 7% Capacity Loss 8%	Tx Pwr 3.5 dB inc. Blocked Calls 11%
-108 dBm	C/I 17 dB dec. MOS 0.7 dec. Dropped Calls 4% Capacity Loss 5%	C/I 12 dB dec. BER 1.7% inc. MOS 0.2 dec. Blocked Calls 28% Dropped Calls 50% Capacity Loss 30%	Tx Pwr 3.8 dB inc. Blocked Calls 33% Overflowed Calls 33% Capacity Loss 33%

Notes on Table 4.5-A (above):

1. The "Effects to System Performance" in the table above, denote the increase (inc.) or decrease (dec.) of the performance metric specified, as compared to the baseline test reference level. "No effect" specified in the table above, is used to denote equivalent performance to the baseline tests, as observed in the test results of the suburban terrestrial test site.
2. The injected interfering signal was performed with a modulated carrier simulating the AirCell signal, and at a steady state level for each test (level ref. to input of cell site).
3. The Baseline test is the reference level, with no injected signals. For all technologies, the performance of the baseline test is 0% Blocked Calls, 0% Dropped Calls, 0% Overflowed Calls, and 0% Capacity Loss.
4. The actual market noise floor conditions are used in these tests, with the terrestrial test cell site is operating and configured in its normal mode.

5 Typical Aircraft & Air Traffic Research

5.1 General and Commercial Aviation Aircraft

This section includes information with respect to general and commercial aviation aircraft. It includes typical cruising speeds, altitudes, and landing patterns.

Commercial Aviation

- This is the commercial airline industry, which has regional, domestic and international air travel services on routine scheduled flights for the general public.
- Typical Aircraft include midsize to heavy Jet Aircraft and small to mid-sized turbo props. These are pressurized aircraft.

Commercial Charter Service

- This includes large and small airport accessibility for non-scheduled flights by rental. These are usually associated with small company business flights or special interest groups.
- These airplanes typically use general aviation airports, or smaller commercial airports.
- Typical Aircraft include small to medium jets, small to medium turbo props, and twin engine piston planes. These can be either pressurized or not, depending on the aircraft.

General Aviation

- This category includes private and small business planes, which are generally privately owned and operated, and could provide some services but typically limited to personal use.
- Typical Aircraft include small single and twin engine piston aircraft, including Piper, Cessna, Beach and Mooney models. These aircraft are usually not pressurized.

Table 5.1-A Typical Aircraft Flight Attributes

Typical Aircraft Flight Attributes *[1]						
	Typ. Cruising Speed	**Typical Cruising Altitude**		**Typ. Landing/ Pattern Speed**	**Typical Landing Pattern**	**Typical Landing Arc Pattern**
	(mph) *[2]	**Short Trips**	**Long Trips**	**(mph) *[3]**	**Altitude *[4]**	**Radius *[4]**
Large & Small Jets 747,737,MD80,Learjet (Pressurized)	450-550	18-28 K ft	33-40 K ft	150-225	3-4 K Ft *[6]	Straight pattern typ.*[6] & 10-20 mile arc
Large & Small Turbo Props Beach King Air (Pressurized)	250-300	12-18 K ft	16-26 K ft	100-175	2-4 K ft	5-10 mile arc & Straight pattern
Single & Twin Pistons Non-pressurized	90-200	3-8 K ft	5-10 K ft	70-125	1-1.5 K ft *[5]	2-4 mile

Notes on Table 5.1-A Typical Aircraft Flight Attributes:

1. The data in Table 5.1-A above represent typical values. The actual ranges of values may vary based upon actual airplane specifications, airport location, individual cases, local conditions, and air traffic controller instructions. This information is based on V-COMM's research as well as discussions with local aviation pilots.

2. These are typical airplane cruising speeds in miles per hour (mph), relative to ground speed, with no wind. Wind speeds can vary these speeds by 0-50 mph, at lower altitudes (i.e. below 10,000 ft), and by 0-100 mph at higher altitudes (i.e. above 30,000 ft).

3. These are typical airplane speeds while landing or taking off, in miles per hour (mph), relative to ground speed.

4. These are typical airplane altitudes while landing. The actual ranges of values vary considerably, by airplane specifications, airport location, individual cases, local conditions, and air traffic controller instructions.

5. Small general aviation airports usually have a pattern approach at 1000 to 1500 feet above the base elevation for the facility. The pattern speed will vary with different aircraft, which allows the aircraft to slow for final approach, above its "stall" speed by a safe margin. If a plane is delayed for landing, in most cases, the pattern speed is used to suspend the aircraft in a conservative safe area within range of the airport.

6. For Commercial Aviation, the pattern altitude could be as much as twice as high as a private class airport. Larger Aircraft demand more speed and runway to establish a safe glide slope for landing. Stacking of aircraft for delayed landings are similar to smaller aircraft with respect to speed but the altitude is determined by an air traffic controller for that area. For commercial aircraft, typical landing patterns are straight into an airport, or curving around a 180 degree arc pattern. In some cases, the landing flight pattern is circuitous to accommodate busy airspace environments, and air traffic procedures established by local aviation controllers.

5.2 Regional Air Traffic Statistics

V-COMM performed the following research regarding regional air traffic reports and statistics. These reports provide a general idea of the types and amount of flights that occur in this region of the country. This information was considered in the development of the case study in Section 6.

FAA Source – Air Traffic Report

The FAA source[41] provides information pertaining to the air traffic environment in the region of the New York, New Jersey & Philadelphia metropolitan area. The airports in this metropolitan area (Newark, J.F. Kennedy, LaGuardia, & Philadelphia Airports) serve up to 8,000 flights a day and accommodate more than 99 million passengers in a year. It is one of the busiest regions for air traffic in the United States.

The air traffic environment in this metropolitan area is characterized by an ever-increasing demand on the air traffic system. The major airports in the area experiencing severe delays are Newark International (EWR), John F. Kennedy International (JFK), LaGuardia (LGA), and Philadelphia International Airport (PHL). The proximity of the facilities results in complex pilot/controller and controller/controller coordination and circuitous flight paths.

The New York/New Jersey/Philadelphia metropolitan air traffic environment was designed and implemented in the 1960's. The volume of air traffic and the types of aircraft that use the airports and the air traffic control system have changed significantly. The system has evolved beyond its originally designed procedural and operational capacity. As a result the area services over 8,000 flights a day and ranks 4 out of the 10 most delayed airports in the United States.

The Port Authority of NY & NJ Source – Air Traffic Report

The NY & NJ Port Authority's Air Traffic Report for year 2000 included 1,178,643 aircraft movement, for Newark, NJ; J.F. Kennedy, NY; and LaGuardia, NY airports. In 1998, they reported the Teterboro, NJ Airport adds 184,488 aircraft movement, and Air Cargo air traffic subtracts 42,614 aircraft movements. The total annual aircraft movement for the NY & NJ area is approximately 1,321,000.

In its 1998 Air Traffic Report, The Port Authority of NY & NJ reported average daily departures for non-stop passenger service to Washington, D.C. from J.F. Kennedy, NY Airport is 35, Newark, NJ Airport is 33, LaGuardia, NY Airports is 45. The average daily

[41] The FAA source providing information pertaining to the air traffic environment in the region of the New York, New Jersey & Philadelphia metropolitan area, is the FAA Eastern Region Air Traffic Division, in the Airspace Resign Project. Additional information is available at http://www.faa.gov/programs/airspace.htm

departures for non-stop passenger service to Washington, D.C. from the NY & NJ commercial airports is 113.

Further, the Washington, D.C. destination is the top destination from the NY & NJ commercial airports. The second and third top destinations are Boston, MA with 103 average daily departures, and Chicago, IL with 80 average daily departures from the NY & NJ commercial airports. The total number of daily non-stop departures from the NY & NJ commercial airports is 1290. This air traffic data is provided from the Port Authority of NY & NJ – 1998 Air Traffic Report.

5.3 Regional Air Traffic Pathways & Terrestrial Cell Sites

The two figures included at the end of this section were attained from the FAA's metropolitan airspace project that is on-going in the northeast. These figures denote the typical air pathways used for this region. Additional air traffic pathways for the NY & NJ, and Philadelphia areas are included in appendix Section 9.15 of this report.

Figure 5.3-A includes take-off and landing patterns of the 4 major airports in the New York & New Jersey area, including Newark & Teterboro in NJ, and JFK & LaGuardia in NY. Due to the density of air traffic in this area, the landing (red) and take-off patterns (green) vary considerably. For landing patterns it varies from as low as 4K feet up to 19K feet, and for take-off patterns from 6K feet to 17K feet. Therefore, the amount of air traffic that exists below 10K feet will be considerable in this area and other major cities in the U.S. In addition, these landing and take-off patterns extend to considerable distances from the respective airports, i.e. approximately 40 miles away.

Figure 5.3-B provides the flight tracks in the NY, NJ & Philadelphia metropolitan airspace region. This figure demonstrates the density and variation of typical flight paths in this area. With this density and variation of flight paths, on-board AirCell units have the potential to affect every terrestrial cell site in the area that is co-channel with its operations.

All currently operating terrestrial cell sites in this area have been super-imposed on this FAA Flight Track exhibit (yellow dots in Figure 5.3-B), to show the cell site density with respect to the flight tracks. With this density and distribution of cell sites and air traffic, the probability of interference to the terrestrial system is tremendous. The terrestrial cell sites are from one of the cellular carriers in the area, and represent a total of 1,631 cell sites. This represents a significant amount of cellular traffic in this busy northeast corridor of United States. Interference to only a fraction of this cellular traffic, would represent a significant number of terrestrial cell sites and telephone calls affected. Included in the Case Study (Section 6 of this report) is an example of a typical flight, and the estimated number of affected terrestrial cell sites and telephone calls.

The significant compatibility issue associated with the AirCell system is portrayed in this characterization of their system. In contrast, AirCell frequently characterizes its system as collocating at terrestrial cell sites in rural markets, which is not the relevant compatibility issue. The compatibility issues reside with the AirCell airborne transmissions and the effects to the terrestrial cellular system. And, with the density of cell sites, cellular traffic, and air traffic in this area, the probability of interference to the terrestrial system is tremendous.

Furthermore, with AirCell base stations located in rural markets, additional compatibility issues arise. In this arrangement, when the AirCell airborne mobile is closer to areas of higher population density, the mobile is more likely to transmit at higher power levels,

since it is further away from its serving AirCell site.[42] In this example, the AirCell airborne mobile is more likely to cause harmful interference to the terrestrial network due to the higher transmitting power, in conjunction with, a closer proximity to a greater number of terrestrial cell sites. And, in these populated areas, the probability of interference to the terrestrial system is incredible when considering the density of terrestrial cell sites, cellular traffic, and air traffic in these areas.

[42] With AirCell's DPC function, its mobile transmit power increases when it is further away from its serving AirCell base station. When AirCell base stations are located in rural markets, the airborne mobile is more likely to transmit at higher power levels when it is closer to more densely populated areas, with higher densities of terrestrial sites and cellular traffic.

Figure 5.3-A Regional FAA Air Traffic Pathways: NY & NJ Area, Existing South Flow

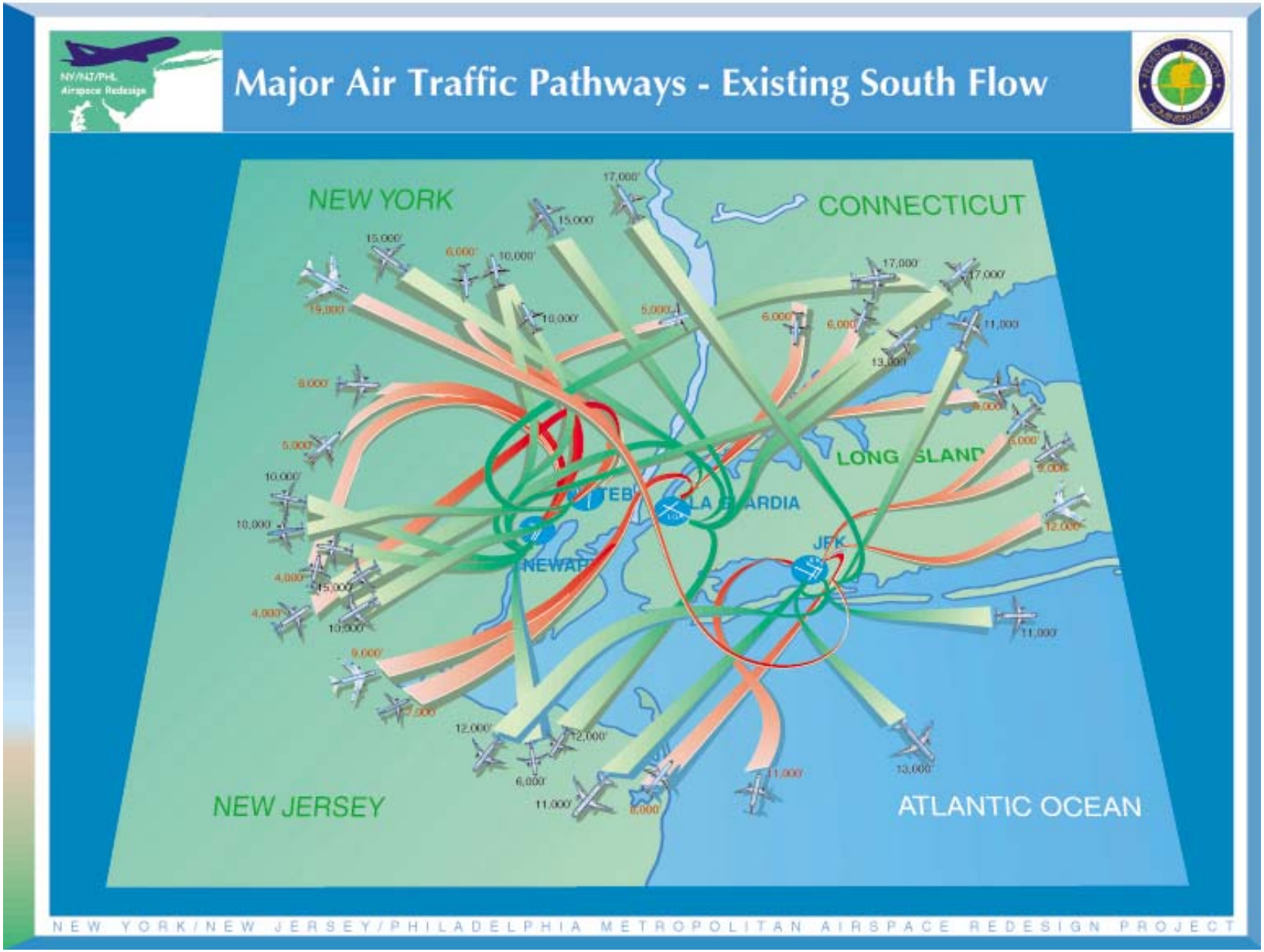
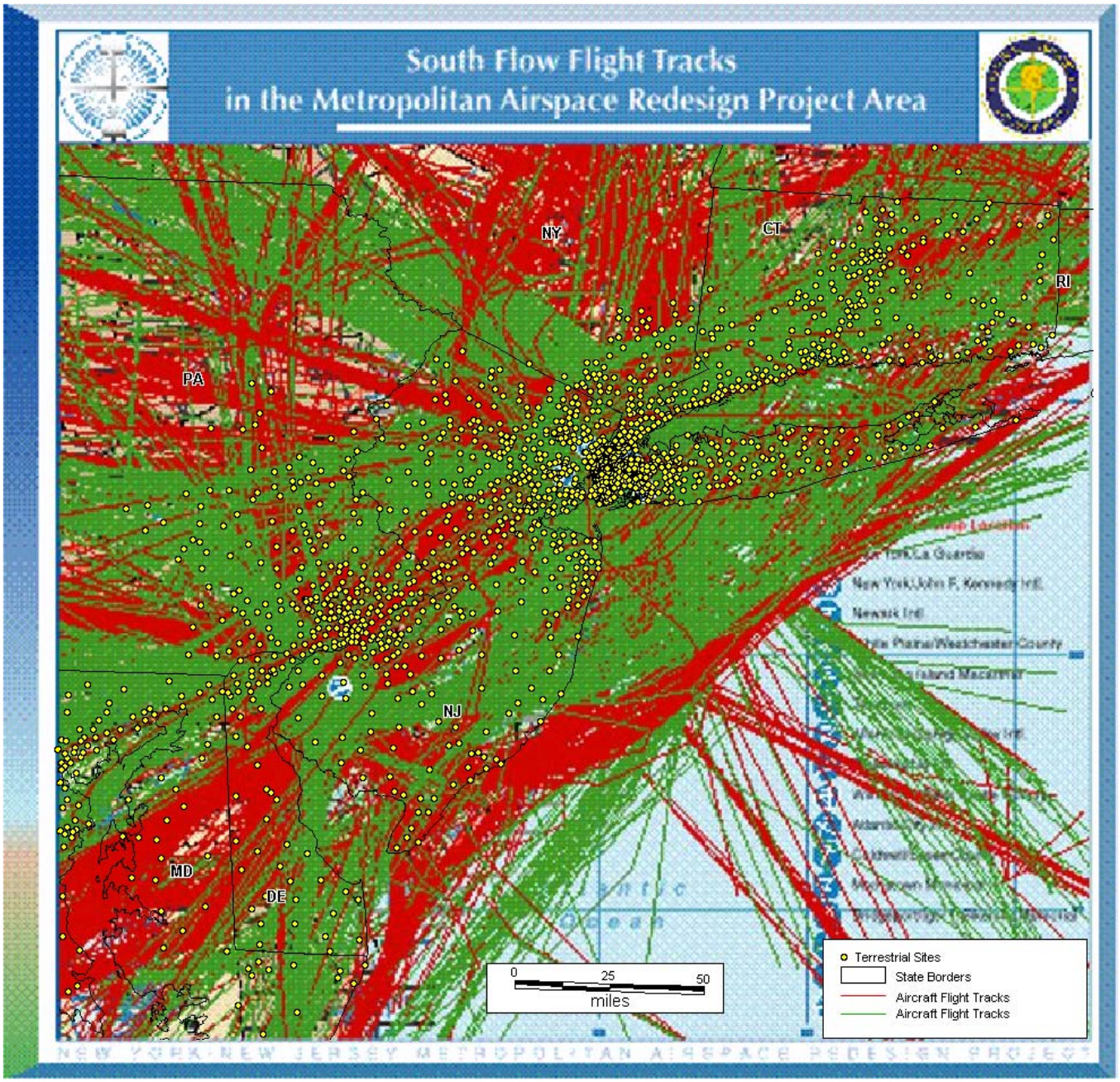


Figure 5.3-B Regional FAA Aircraft Flight Tracks & Terrestrial Cell Sites



5.4 National Air Traffic Statistics & Flight Data

V-COMM performed the following research regarding national air traffic reports and flight data. This data provides information regarding the distribution and density of flights, and the amount of flights that occur within the United States.

National Air Traffic maps depicting actual flight data are provided in Figure 5.4-A and Figure 5.4-B, on the following pages. This flight data is from Flightview, which is a national flight tracking system that provides radar-based flight data.[43] These exhibits show the distribution of actual flights to the major airports Chicago and Atlanta. Other flight data exhibits are provided in Appendix Section 9.15, for the major airports in Los Angeles, Philadelphia, Dulles, JFK, San Francisco, and Miami.

These exhibits display all commercial airborne flights as dots, while flights to "airports" are shown as airplanes. The location of each commercial airborne flight was determined by the radar-based tracking. This map does not necessarily show all of the airborne flights at that particular time, as some companies have opted not to share their flight location information with the general public. Also, this only represents the Instrument-based Flights (IFR), and not Visual-based flights, or other general aviation flights.

In these exhibits, the number of flights displayed is typically between 3,400 and 3,800 flights during the day. As observed in the exhibits, the density of flights is heavily concentrated within the metropolitan areas, and along certain flight pathways. Other flights are randomly distributed throughout United States. And, in the populated areas, the probability of interference from AirCell's use of cellular spectrum is tremendous when considering the density of terrestrial cell sites, cellular traffic, and air traffic in these areas.

<u>Federal Bureau of Transportation Source – Air Traffic Report</u>

In comparison to the Regional Air Traffic Statistics in Section 5.2, the National Air Traffic Statistics are as follows. The total number of commercial aircraft scheduled departures for passenger service in the United States in the year 2000 was 8,991,681. This data is from the Bureau of Transportation Statistics, Washington, D.C.

[43] FlightView has been the flight tracking system of choice for commercial airlines, general aviation, airports, and ground transportation companies, for over eight years. FlightView offers highly accurate up-to-the-minute data on IFR flights in the United States, and features the most advanced technologies available for gathering, processing and distributing accurate, radar-based flight information.

Figure 5.4-A National Air Traffic Data – Flights to Chicago

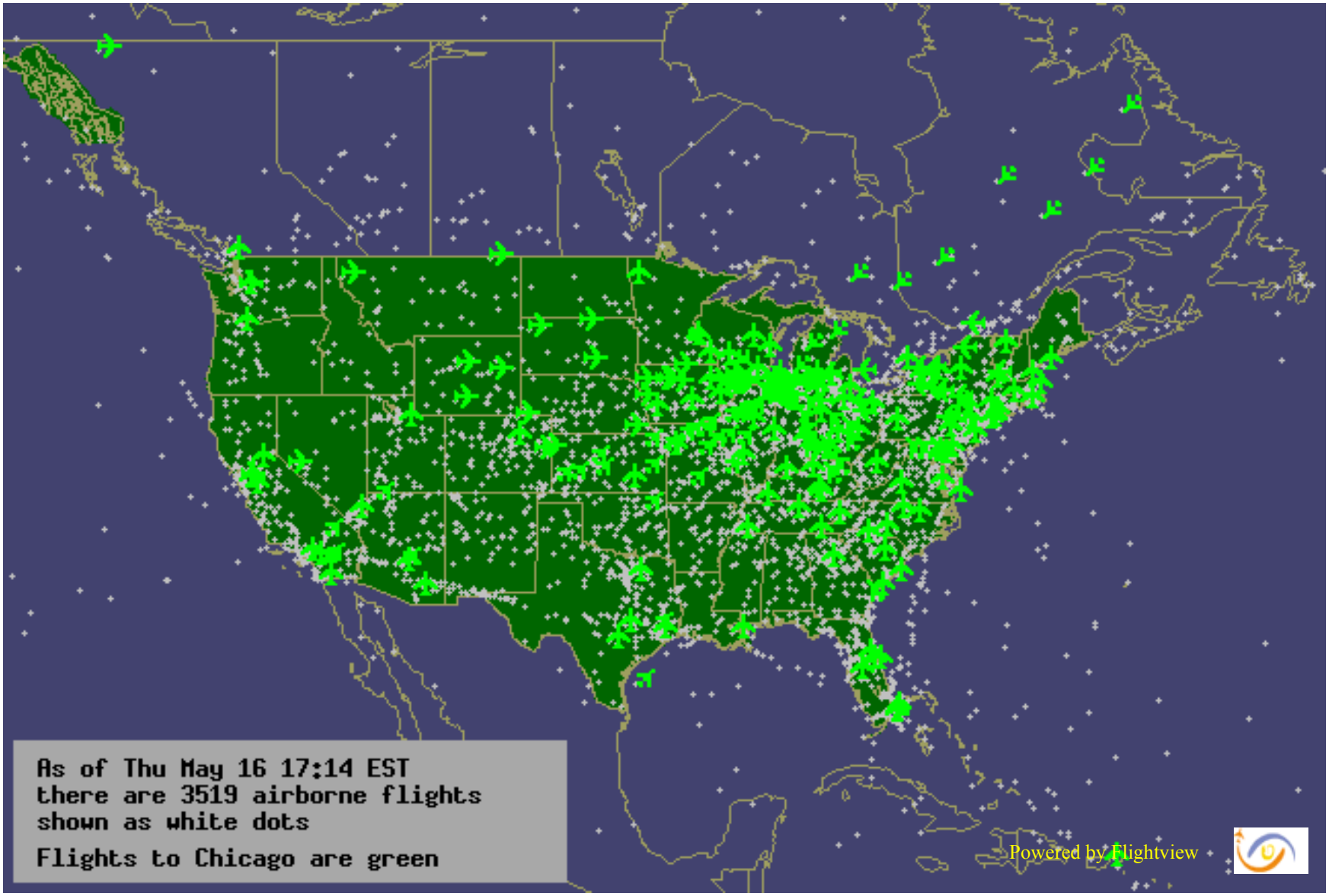
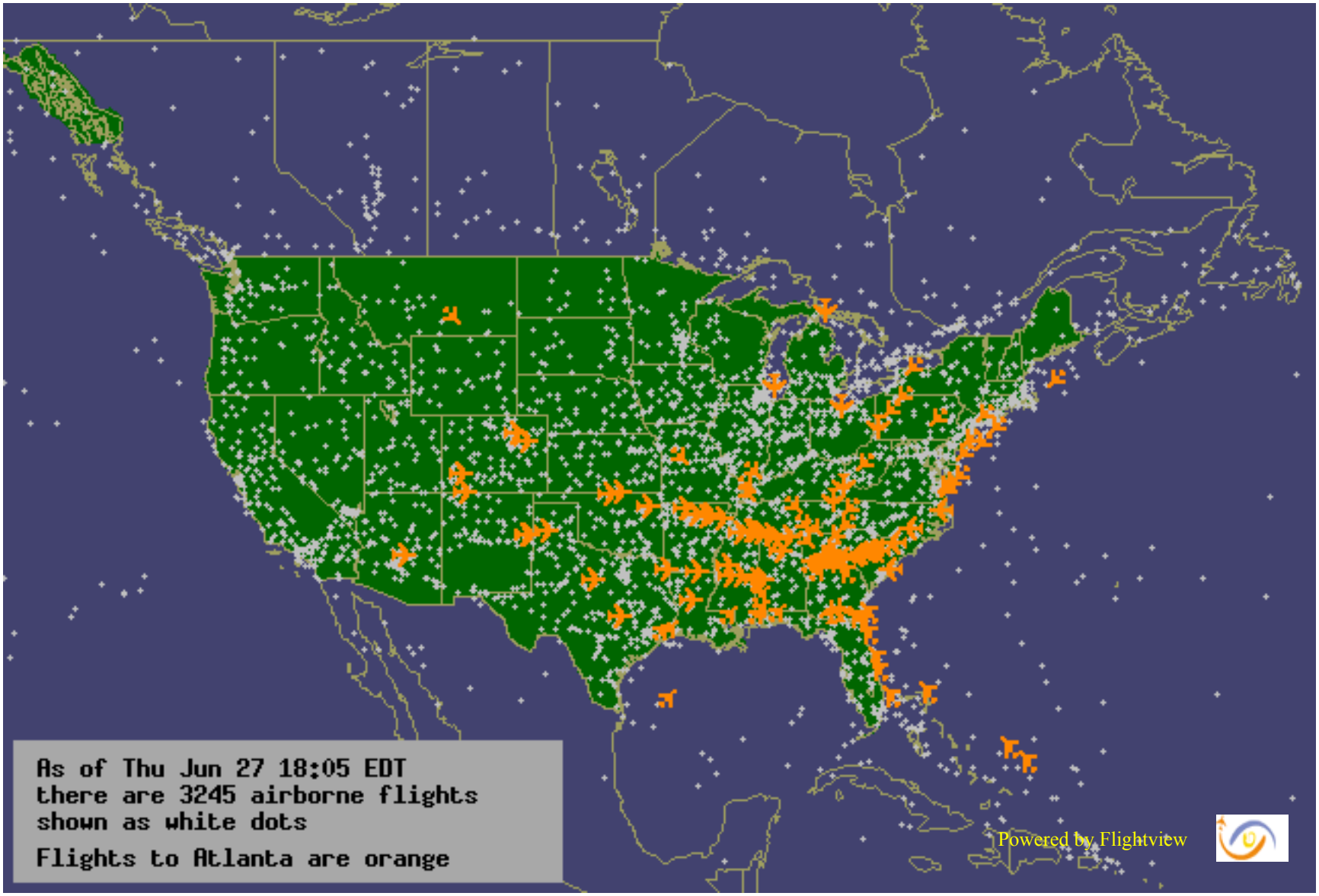


Figure 5.4-B National Air Traffic Data – Flights to Atlanta



6 Case Study – Flight from Washington, DC to Teterboro, NJ

6.1 Purpose

V-COMM developed a Case Study of a typical flight within the market areas tested, in Phase 1 and Phase 2 tests conducted under the AirCell Compatibility Test Plan. Rather than a statistical probability study spread across the country, this Case Study attempts to provide insight to a realistic number of terrestrial cell sites which would be affected by receiving harmful interfering signals from an AirCell equipped aircraft flying this flight path profile. The defined levels of interference are based upon the results of prior Phase 1 and Phase 2 tests. Additionally, the Case Study is considered to provide a conservative insight, as to the impact of harmful interference from AirCell transmissions to terrestrial cellular networks. This conservative approach uses the results from Phase 1 flight tests, and a conservative threshold from Phase 2 tests, as an interference analysis point, as defined below.

6.2 Case Study Setup

6.2.1 Aircraft Flight Profile

The flight profile used for the case study takes into consideration a flight between Dulles Airport, Washington, D.C. and Teterboro Airport in Teterboro, NJ. These areas contain two heavy usage General Aviation facilities. In fact, Teterboro is the largest General Aviation airport in New Jersey. This particular flight path has commercial traffic of approximately 113 flights daily, in either direction. Additionally, Washington, D.C. is the top destination for non-stop flights departing from NY/NJ area airports. V-COMM researched actual flight plans between these destinations and verified the flight plan with local pilots. V-COMM also referred to pilot handbooks for typical ascent, descent, airspeed and landing statistics to utilize for this flight path profile. Therefore, this flight profile along this corridor represents a very typical profile and one that would likely be chosen by General Aviation as well as Commercial aircraft.

The case study considers two types of aircraft for this corridor, jet and piston. These aircraft are typical of general aviation traffic utilized in this corridor and have different flight characteristics (speed, altitude, etc.) and therefore potentially different impacts on the cell sites.

The flight profile case study takes into account all of the different aspects of the flight, including take-off, ascent, cruise, descent, and landing. The two aircraft have different characteristics with respect to these flight aspects and thus provide insight into the effects of the AirCell equipment on terrestrial cellular base stations from two perspectives that are representative of common aircraft and flight patterns.

Figure 6.2-A below depicts the Aircraft Flight – Path Profile. This figure depicts the altitude profile with respect to the distance between the two airport facilities. The significant difference between the two aircraft is the cruising altitude. Figure 6.2-B depicts the Aircraft Flight – Time Profile. This figure depicts the flight profile with respect to the time between the two airport facilities. The significant difference in these plots is the time at which the aircraft spend in the respective aspects of flight. The data used to generate these figures can be seen in Table 6.2-A.

At the altitudes depicted in these flight profiles, the aircraft will be "line of sight" with over 2,500 terrestrial cell sites that receive the AirCell airborne mobile signals.[44]

[44] At the flight altitude of 7,000 ft and 19,000 ft. AGL, the aircraft will be line of sight (LOS) with terrestrial cell site antennas that are within 102 and 169 miles of the aircraft, respectively, assuming a smooth earth and terrestrial antennas mounted above tree-line obstructions on average terrain elevation. To calculate the LOS distance (D) to the horizon, the formula D = square-root (1.5 * H) is used, where H is the height above average terrain, in feet.

Figure 6.2-A Aircraft Flight: Altitude & Distance Profile

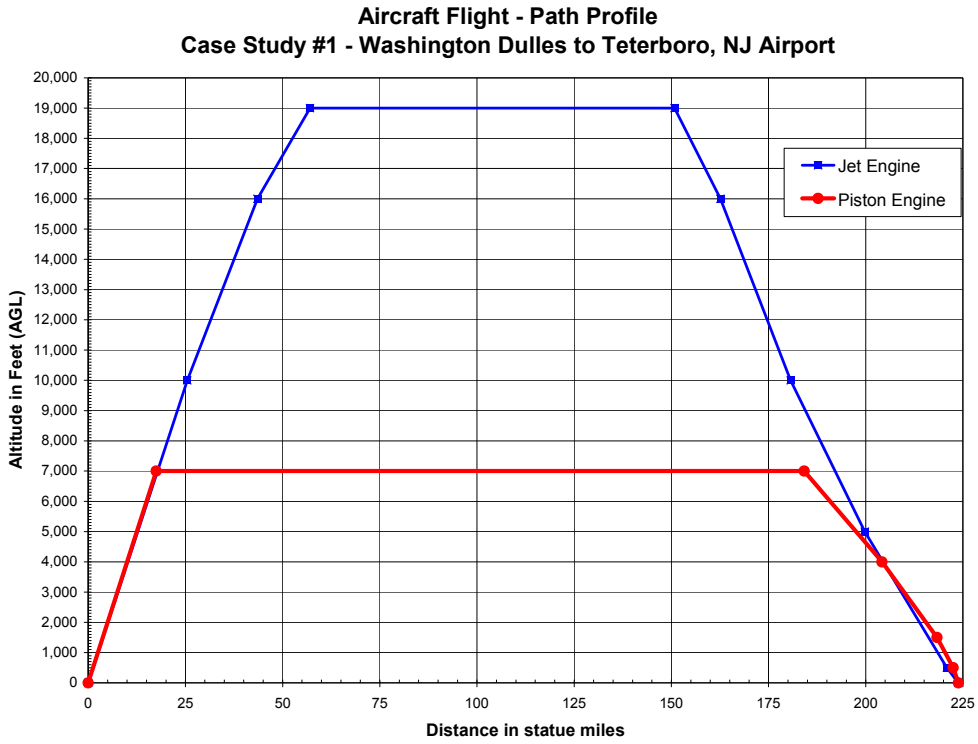


Figure 6.2-B Aircraft Flight: Altitude & Time Profile

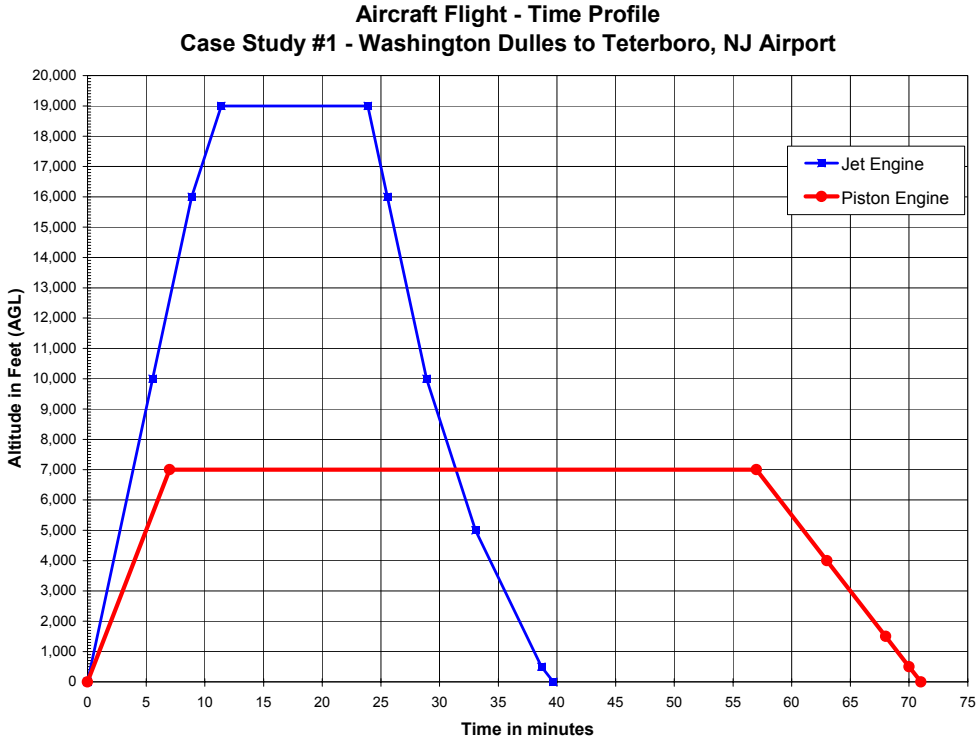


Table 6.2-A Data Sheet Analysis: Aircraft Flight Profile – Dulles Washington to Teterboro, NJ Airport

Aircraft Flight Profile

Twin Engine Piston Aircraft (Non-Pressurized)

Departure Airport - Washington Dulles International Destination Airport - Teterboro, NJ

Altitude Ft. AGL	Rate of Climb / Rate of Decent Ft./min	Flight Profile	Airplane Speed MPH	Airplane Speed Miles/min	Leg	Time (minutes) Fm Depart	Time (minutes) Fm Arrive	Distance (miles) Fm Depart	Distance (miles) Fm Arrive
0	-	Takeoff	-	-	0	0	71	0	224
7000	1000	Ascending	150	2.5	7	7	64	18	206
7000	- Cruising -	Cruising	200	3.3	50	57	14	184	40
4000	500	Descending	200	3.3	6	63	8	204	20
1500	500	Descending	170	2.8	5	68	3	218	6
500	500	Approach	125	2.1	2	70	1	223	1
0	-	Landing	80	1.3	1	71	0	224	0

% Time @ Cruising Altitude = 70.4%

Jet Engine Aircraft (Pressurized)

Departure Airport - Washington Dulles International Destination Airport - Teterboro, NJ

Altitude Ft. AGL	Rate of Climb / Rate of Decent Ft./min	Flight Profile	Airplane Speed MPH	Airplane Speed Miles/min	Leg	Time (minutes) Fm Depart	Time (minutes) Fm Arrive	Distance (miles) Fm Depart	Distance (miles) Fm Arrive
0	-	Takeoff	-	-	0	0	40	0	224
10000	1800	Ascending	275	4.6	5.6	6	34	25	198
16000	1800	Ascending	325	5.4	3.3	9	31	44	180
19000	1200	Ascending	325	5.4	2.5	11	28	57	167
19000	- Cruising -	Cruising	450	7.5	12.5	24	16	151	73
16000	1800	Descending	425	7.1	1.7	26	14	163	61
10000	1800	Descending	325	5.4	3.3	29	11	181	43
5000	1200	Descending	275	4.6	4.2	33	7	200	24
500	800	Approach	225	3.8	5.6	39	1	221	3
0	500	Landing	175	2.9	1.0	40	0	224	0

% Time @ Cruising Altitude = 31.5%

6.2.2 Terrestrial Cell Sites

In order to determine the impact on terrestrial cell sites, the relationship of the cell sites to the flight path has to be established. All currently operating terrestrial cell sites along or nearby the flight path profile have been mapped in Figure 6.3-A. This cell site distribution is from one of the cellular carriers and represents a cell site density that is expected within the flight profile. A total of 2,681 terrestrial cell sites are depicted. From that mapping, a relationship of these sites to the flight path is established.

For AMPS and TDMA cellular systems, the terrestrial sites which would be co-channel with the AirCell cell sites would be the sites of concern. In order to develop a co-channel mapping, an N=7 frequency re-use plan has been considered. Using this plan, the co-channel sites were depicted in a different color on the map. For CDMA cellular systems, all terrestrial cell sites would be co-channel with the AirCell call in progress, since CDMA systems utilize N=1 frequency reuse, or every channel is used in every cell site and sector.

6.2.3 Interference Analysis Point (IAP)

Based on the analysis of the data resulting from the Phase 2 tests, an Interference Analysis Point (IAP) has been established for this Case Study. This IAP is the level at which an interfering signal has an undisputed effect on all technologies (AMPS, TDMA, & CDMA),[45] and causes significant harmful interference to terrestrial cellular service. The IAP signal level was chosen based upon the results of Phase 2 tests performed at the terrestrial suburban test site. At this level, regardless of technology chosen, significant harmful interference will occur, thereby degrading terrestrial cellular system performance. Further, for purposes of simplicity when developing this Case Study, a single IAP is chosen. This will help demonstrate a realistic number of affected terrestrial cells, regardless of technology. The value of the IAP used in this Case Study is -114 dBm.

The -114 dBm IAP value was chosen to demonstrate that a significant number of terrestrial cell sites and telephone calls would be affected, *even at this IAP value*. If a lower IAP value is used (below -114 dBm), the results would have shown substantially more terrestrial cell sites and telephone calls are affected, in comparison to the results provided in this case study section.[46]

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[45] This IAP is based on Phase 2 test results for terrestrial cellular systems using AMPS, TDMA, and CDMA technologies. For CDMA systems, this represents the Phase 2 test results for 1 injected signal on the CDMA carrier.

[46] Interfering signals received at terrestrial sites below -114 dBm have the potential to cause harmful interference to the terrestrial system for all technologies (AMPS, TDMA & CDMA), as described in Section 4 of this report.

6.3 Methodology

With the flight path, cell site locations, and IAP established, the effects of the airborne AirCell equipment transmitting along this flight path can be developed. The procedure for developing the impact to the terrestrial system is as follows:

1.) Choose several waypoints along the flight path - The waypoints were chosen uniformly using a combination of distinct aircraft altitude points, and distinct change in heading points along the flight path. The breakout of points is documented in Table 6.3-A and Table 6.3-B below.

2.) For each of the waypoints chosen, the AirCell Dynamic Power Control (DPC) Level was calculated. A DPC value can range from 3 to 7 as per the Phase 1 tests performed for the serving AirCell Marlboro, NJ site. Other AirCell sites have a maximum DPC level 2, which is 4 dB higher than DPC level 3 (see Section 7.6). Each level represents a 4 dB increase to the AirCell mobile transmit power level. Flight tests in Phase 1 with DPC disabled were performed at a DPC level fixed at 2. Therefore, for any waypoint whose DPC level is greater than 2 (i.e. DPC number is greater but signal is lower), an RSSI adjustment was required to the received signal levels for the Phase 1 tests at fixed maximum power (DPC level 2) by the appropriate 4 dB decrement.[47]

3.) With the DPC and IAP established for each chosen waypoint, a circle of interference can be calculated around the waypoint, using the results of Phase 1 tests. This circle represents the ground surface area that would receive AirCell signals at an RSSI level of equal to or above the IAP. It is recognized that for a particular point in space and time, the pattern would not be a true circle due to the radiation pattern of the AirCell antenna. However, if one were to perform an iterative process among thousands of waypoints along the flight path, the circle would extend along the flight path axis. This representation is accomplished in the next step.

4.) With the circle of interference established in step 3, the points at the outside of the circle furthest from the flight path can be connected resulting in an oblong area of interference. Terrestrial cell sites within this oblong area would receive signal strengths at a level equal to or greater than the IAP, and would therefore experience harmful interference.

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[47] This case study analyzes the potential interference caused by an AirCell call on a voice channel, which is controlled by the DPC function. Potential interference caused from an AirCell “control channel” is not considered in this case study. To analyze the affects of AirCell “control channels” to terrestrial cellular systems, no adjustments to the RSSI levels are necessary since the transmissions are at maximum mobile power all the time, and therefore, the results would show more affected terrestrial cell sites than presented in this case study.

5.) For CDMA cellular systems with a frequency reuse of N=1, all terrestrial cell sites within this oblong would suffer since AirCell would be operating in the CDMA carrier band. For TDMA & AMPS terrestrial cellular systems, the interference would occur on approximately 1 of 7 cell sites within the oblong assuming a "standard" N=7 frequency re-use plan.[48]

[48] Terrestrial TDMA / AMPS cellular systems using N=7 frequency reuse plans are assumed in this case study. The N=7 reuse plan is a nominal and conservative estimate for a typical system, but carriers are not limited to it, and will use other reuse plans to accommodate market demands and system loads. For example, some cellular systems use N=5 and other flexible frequency assignment algorithms that utilize higher reuse plans.

Figure 6.3-A Airplane Path Profile & Terrestrial Cell Sites

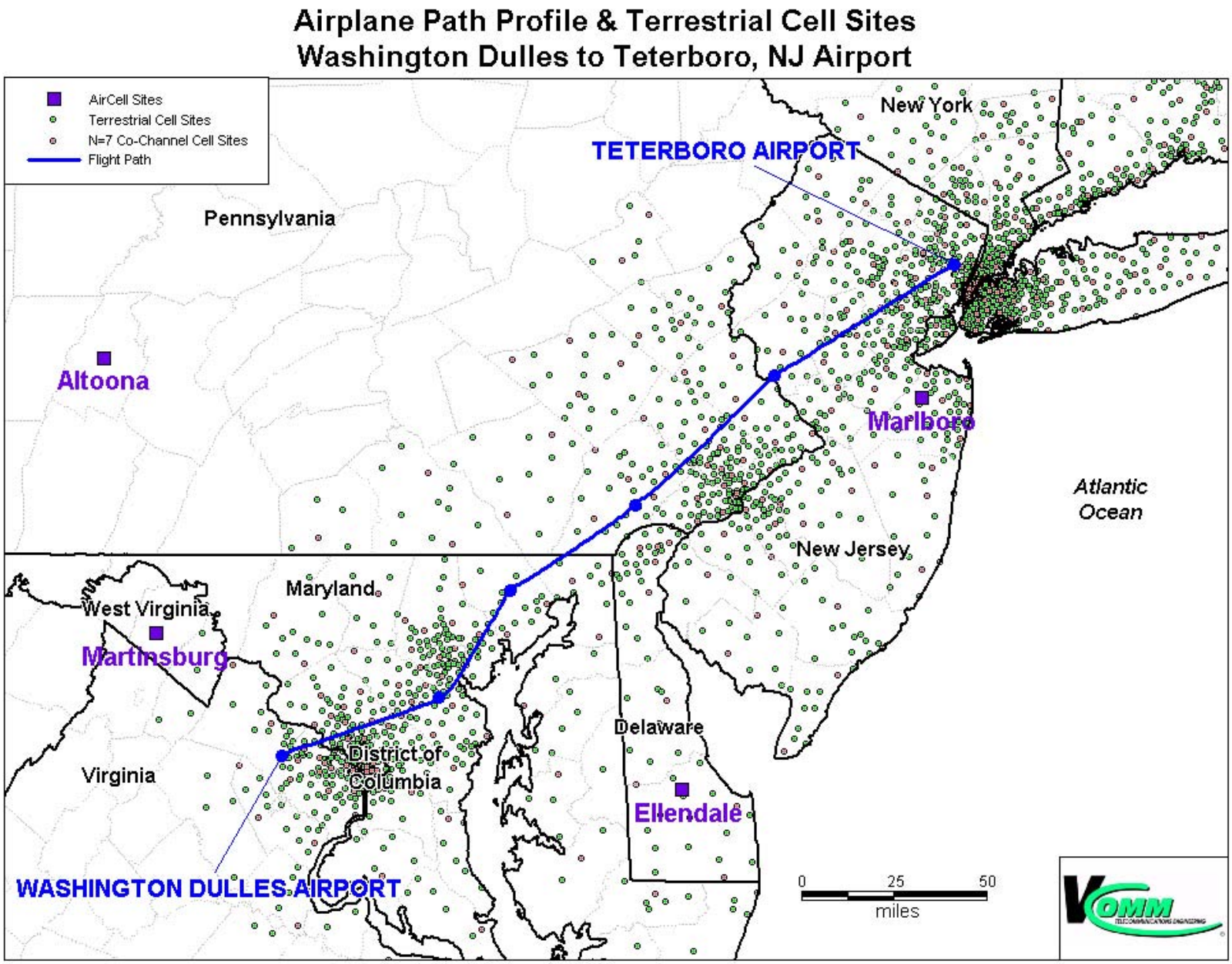

Table 6.3-A Data Sheet Analysis: Affected Terrestrial Cell Sites, SL45 Terrestrial Antenna, Jet Aircraft

Affected Terrestrial Cell Sites along flight path DC to NJ, for SL45 Terrestrial Antenna, Jet Aircraft

Flight Waypoint #	Airplane Altitude (ft, AMSL)	Airplane Distance (mi) Fm Dulles	Airplane Distance (mi) Fm Teterboro	AirCell Serving Site [5]	Distance Fm AirCell Serving Site	AirCell [2] Mobile DPC Level	dB Offset [3] for RSSI	Distance (mi) [1] to Terrestrial Site Average	Distance (mi) [1] to Terrestrial Site 90%	Average RSSI # of Affected Terrestrial Sites [4] Total	Average RSSI # of Affected Terrestrial Sites [4] 1/7 Total	90% RSSI # of Affected Terrestrial Sites [4] Total	90% RSSI # of Affected Terrestrial Sites [4] 1/7 Total
1	2,000	5	219	WV	50	4	-8	11	39	51	7	321	46
2	5,000	12.5	211.5	WV	55	3	-4	21	42	239	34	399	57
3	10,000	25	199	WV	63	3.25	-5	30	42	354	51	424	61
4	19,000	57	167	WV	82	3	-4	50	56	424	61	490	70
5	19,000	79	145	DE	71	3.5	-6	37	55	160	23	324	46
6	19,000	123	101	DE or NJ	80	3	-4	50	56	348	50	396	57
7	19,000	151	73	NJ	51	4	-8	30	42	226	32	351	50
8	10,000	181	43	NJ	31	4	-8	5	42	5	1	440	63
9	5,000	199	25	NJ	27	3	-4	21	42	194	28	760	109
10	2,000	215	9	NJ	32	5.75	-15	5	21	22	3	468	67
				Average =	54.2	3.7	-6.6	26.0	43.7	202	29	437	62
				Std. Dev.=	20.0	0.9	3.4	16.5	10.4	146	21	127	18
									Total Affected Terrestrial Cell sites [4]:	**995**	**142**	**1564**	**223**

Notes for Table (above):

1. The data sheet above represents the number and distances to the affected terrestrial cell sites for the the Phase 1 Flight Test Results. An Interference Analysis Point (IAP) of -114 dBm for AMPS, TDMA & CDMA technologies is used to determine the approximate distance for consistent AirCell Signal Levels. These are the distances from the Airplane to the terrestrial cell site, using the IAP as a threshold, the pathloss (AirCell signal strength) from the DPC Disabled Flight Tests, and the average AirCell Mobile DPC level from DPC Enabled flight tests. The Average and 90% RSSI Levels, from the DPC Disabled flight tests graphs for the specified flight altitudes and airplanes, are used to determine the distances to the signal level crossing. A RSSI "dB Offset" for AirCell mobile Tx Power is observed from the DPC Enabled flight test results. The resultant distances are the radius' of the circles for the Flight Map Exhibit, with Affected Terrestrial Cell Sites.

2. This analysis uses the "average" AirCell mobile DPC level, as observed for the "Average DPC Levels" line from the DPC Enabled flight test results. These AirCell mobile DPC levels are observed for the specified flight altitudes, airplanes and distances from the AirCell Marlboro, NJ site.

3. This analysis uses a "dB Offset for RSSI", which is assessed from the "Average DPC Levels" from flight tests with DPC Enabled. For this analysis, this dB value is used to lower the AirCell signals levels received at the terrestrial site, from the Phase 1 Flight Test Results for the DPC Disabled Flight Tests.

4. The Total # of Affected Terrestrial Sites are computed from the "airplane to terrestrial cell" Distances, for the Average or 90% Signal Levels, as listed above. The Total and 1/7 Total data is computed from the cell sites on Flight Map Exhibit with Affected Terrestrial Cell Sites. The "Total Affected Terrestrial Cell sites" are unique, which have the duplicated cell sites removed from the individual waypoint counts for the overlapping circles.

5. This analysis uses the closest AirCell site as the serving AirCell site for each waypoints above, which assumes that the AirCell airborne mobile will be at a more conservative DPC level, which is at lower power.

Table 6.3-B Data Sheet Analysis: Affected Terrestrial Cell Sites, V-POL Terrestrial Antenna, Jet Aircraft

Affected Terrestrial Cell Sites along flight path DC to NJ, for V-POL Terrestrial Antenna, Jet Aircraft

Flight Waypoint #	Airplane Altitude (ft, AMSL)	Airplane Distance (mi) Fm Dulles	Airplane Distance (mi) Fm Teterboro	AirCell Serving Site [5]	Distance Fm AirCell Serving Site	AirCell [2] Mobile DPC Level	dB Offset [3] for RSSI	Distance (mi) [1] to Terrestrial Site Average	Distance (mi) [1] to Terrestrial Site 90%	Average RSSI # of Affected Terrestrial Sites [4] Total	Average RSSI # of Affected Terrestrial Sites [4] 1/7 Total	90% RSSI # of Affected Terrestrial Sites [4] Total	90% RSSI # of Affected Terrestrial Sites [4] 1/7 Total
1	2,000	5	219	WV	50	4	-8	4	6	10	1	15	2
2	5,000	12.5	211.5	WV	55	3	-4	6	13	26	4	126	18
3	10,000	25	199	WV	63	3.25	-5	4	15	16	2	175	25
4	19,000	57	167	WV	82	3	-4	6	27	20	3	151	22
5	19,000	79	145	DE	71	3.5	-6	0	26	0	0	84	12
6	19,000	123	101	DE or NJ	80	3	-4	6	27	7	1	161	23
7	19,000	151	73	NJ	51	4	-8	0	6	0	0	9	1
8	10,000	181	43	NJ	31	4	-8	4	6	4	1	9	1
9	5,000	199	25	NJ	27	3	-4	6	13	14	2	81	12
10	2,000	215	9	NJ	32	5.75	-15	2	4	5	1	9	1
				Average =	54.2	3.7	-6.6	3.8	14.3	10	1	82	12
				Std. Dev.=	20.0	0.9	3.4	2.4	9.3	9	1	68	10
									Total Affected Terrestrial Cell sites [4]:	**191**	**27**	**652**	**93**

Notes for Table (above):

1. The data sheet above represents the number and distances to the affected terrestrial cell sites for the the Phase 1 Flight Test Results. An Interference Analysis Point (IAP) of -114 dBm for AMPS, TDMA & CDMA technologies is used to determine the approximate distance for consistent AirCell Signal Levels. These are the distances from the Airplane to the terrestrial cell site, using the IAP as a threshold, the pathloss (AirCell signal strength) from the DPC Disabled Flight Tests, and the average AirCell Mobile DPC level from DPC Enabled flight tests. The Average and 90% RSSI Levels, from the DPC Disabled flight tests graphs for the specified flight altitudes and airplanes, are used to determine the distances to the signal level crossing. A RSSI "dB Offset" for AirCell mobile Tx Power is observed from the DPC Enabled flight test results. The resultant distances are the radius' of the circles for the Flight Map Exhibit, with Affected Terrestrial Cell Sites.

2. This analysis uses the "average" AirCell mobile DPC level, as observed for the "Average DPC Levels" line from the DPC Enabled flight test results. These AirCell mobile DPC levels are observed for the specified flight altitudes, airplanes and distances from the AirCell Marlboro, NJ site.

3. This analysis uses a "dB Offset for RSSI", which is assessed from the "Average DPC Levels" from flight tests with DPC Enabled. For this analysis, this dB value is used to lower the AirCell signals levels received at the terrestrial site, from the Phase 1 Flight Test Results for the DPC Disabled Flight Tests.

4. The Total # of Affected Terrestrial Sites are computed from the "airplane to terrestrial cell" Distances, for the Average or 90% Signal Levels, as listed above. The Total and 1/7 Total data is computed from the cell sites on Flight Map Exhibit with Affected Terrestrial Cell Sites. The "Total Affected Terrestrial Cell sites" are unique, which have the duplicated cell sites removed from the individual waypoint counts for the overlapping circles.

5. This analysis uses the closest AirCell site as the serving AirCell site for each waypoints above, which assumes that the AirCell airborne mobile will be at a more conservative DPC level, which is at lower power.

6.4 Case Study Results

For this case study, the flight path between Dulles Washington Airport and Teterboro, NJ airport was chosen. The actual cell site locations for the cellular network operating in the area were obtained and mapped. This figure together with the flight path is depicted in Figure 6.4-B and Figure 6.4-A, for the vertical panel terrestrial antenna (V-POL), and for the cross-polarized terrestrial antenna (SL45), which is growing in deployment. These map figures utilize the aircraft flight plan, the terrestrial cell site locations, and the results of Phase 1 & Phase 2 testing provided in Table 6.3-A and Table 6.3-B. Similar maps and tables for other terrestrial antenna systems are provided in the Appendix Section 9.16.

Ten way points along the flight path were established. As described above, these were chosen based on altitude characteristics, or directional changes in the flight path. Since the different aircraft types (piston and jet) have different climb and descent profiles, the way points and the altitudes for the two aircraft types are different. These map figures are shown with the circles of harmful interference for each aircraft type. The characteristics of each way point with respect to altitude, distance from serving AirCell site, AirCell DPC level, distance to the terrestrial cell site (using the results of Phase 1 tests, and the IAP level from Phase 2 tests), and total number of affected terrestrial cell sites are depicted in Table 6.3-A and Table 6.3-B in this section, and in the Appendix Section 9.16.

A simple program is run to extract the number of terrestrial cell sites that lie within the boundary that contain the circles of interference. Table 6.4-A and Table 6.4-B below summarize the results of the jet aircraft flight profile, outlining the number of affected terrestrial cell sites for the four different terrestrial antenna types, for Average & 90% AirCell Signal Levels received, and for the wireless technologies AMPS, TDMA & CDMA. Terrestrial cellular networks utilizing AMPS & TDMA technologies typically have a frequency reuse of N=7 (1 out of every 7 cell sites use the same frequency), and systems utilizing CDMA technologies have a frequency reuse of N=1 (CDMA frequencies are used in every sector of every cell site).

Table 6.4-A Affected Terrestrial Cell Sites: AirCell Average Signal Level

Affected Terrestrial Cell Sites
AirCell Average Signal Level, Jet Aircraft

Terrestrial Antenna Type	AMPS Cell Sites (N=7)	TDMA Cell Sites (N=7)	CDMA Cell Sites (N=1)
H-POL	222	222	1551
SL45	142	142	995
V-POL	27	27	191
OMNI	29	29	203

Table 6.4-B Affected Terrestrial Cell Sites: AirCell 90% Signal Level

Affected Terrestrial Cell Sites
AirCell 90% Signal Level, Jet Aircraft

Terrestrial Antenna Type	AMPS Cell Sites (N=7)	TDMA Cell Sites (N=7)	CDMA Cell Sites (N=1)
H-POL	230	230	1608
SL45	223	223	1564
V-POL	93	93	652
OMNI	53	53	369

It can be seen in the tables above that as many as 1608 CDMA terrestrial cell sites can be affected by a single aircraft flying a route within this Case Study area. The number of individual cellular telephone calls that can potentially be affected by this single flight is outlined in Table 6.4-C below.

Table 6.4-C Affected Terrestrial Cellular Telephone Calls: SL45 Antenna, AirCell 90% Signal Level, Jet Aircraft

Technology of Terrestrial System	Affected Terrestrial Cell Sites	Affected Voice Channels or Calls per sector	Total Calls Affected along entire Flight Route	Ratio of AirCell Calls to Affected Terrestrial Calls
AMPS	223	1	223	1:223
TDMA	223	3 - 50	669 - 11,150	1:669 - 1:11,150
CDMA	1564	20	31,280	1:31,280

Notes for Table 6.4-C (above):

1. A single AMPS call per terrestrial site would be affected by a single AirCell call.
2. As many as three TDMA calls per terrestrial site would be affected if interference were on a TDMA voice channel, and as many as fifty new calls originating on the sector would be affected if interference were on a TDMA control channel.
3. All calls on the CDMA carrier would be affected. The CDMA carrier is used within every sector of every terrestrial cell site. For the current CDMA phone (EVRC Vocoder), this represents as many as twenty CDMA terrestrial calls per sector, which would be affected by a single AirCell call on the CDMA carrier.
4. For CDMA terrestrial cellular systems, the analysis above represents the effects of only one AirCell signal affecting only one sector of the terrestrial cell site; with no effects to the other two sectors. However, in real world situations, the same CDMA channel is used in all three sectors of each terrestrial cell site, and the AirCell interference can affect multiple sectors within the same terrestrial site. For example, while the airborne AirCell unit is in-between two sectors, it would equally affect two sectors of the same cell site. Assuming two sectors of each terrestrial site are affected, the number of affected terrestrial CDMA cell sites will increase to approximately twice the amount listed in the table above. Also, since CDMA carriers have a channel bandwidth of 1.25 MHz, multiple 30 kHz AirCell signals can interfere with this same CDMA channel, which would cause the number of affected terrestrial cell sites to increase above the values listed in the table above.
5. This analysis assumes that an AirCell call is maintained for the duration of the flight.

6. This analysis assumes the interfering signal is an AirCell voice channel. Potential interference from AirCell "control channels" are not considered in this analysis, and is expected to affect more terrestrial cell sites and calls, with short duration static bursts and disruptions in audio quality of terrestrial cellular service, during AirCell call setup, SMS, or phone auto-registration.
7. For CDMA systems, the analysis above represents the effects to the terrestrial system with an AirCell interfering signal on the CDMA carrier channel.[49]

It can be seen in the above Table 6.4-C that a significant volume of terrestrial calls can be adversely affected by just one AirCell call, on just one flight. In fact, when considering that this flight occurs, on average, 113 times a day, one could extrapolate that the number of individual terrestrial calls affected every day is well over 100 times that shown in Table 6.4-C. Furthermore, when considering that other flights in the NY, NJ and Philadelphia area have similar flight plans, yielding similar results, the affects to the terrestrial cellular system is staggering. For example, the number of flights served in this area is up to 8,000 flights a day, with more than 99 million passengers served annually.

As exhibited in Table 6.4-C above, a significant volume of terrestrial calls can be adversely affected by just one AirCell call, on just one channel. Since multiple AirCell calls on multiple channels are possible,[50] and in fact likely when considering the volume of flights and passengers in this area, an even greater number of affected terrestrial cell sites can be expected.

In conclusion, these are very significant findings, considering that AirCell's use of cellular spectrum is secondary, and the terrestrial licensed cellular carriers use is primary. Intuitively, one would assume the inverse of the ratios outlined in the above table, i.e. that it would require as many as 30,000 AirCell calls to affect 1 terrestrial call.

It should be noted that this Case Study outlines a single flight route in one section of the United States. If this methodology were extrapolated throughout the United States, along flight paths through similarly populated areas, the daily number of terrestrial cellular calls affected by AirCell operations would be very significant. When considering that approximately 35% of all 911 & emergency calls are generated by terrestrial wireless phones,[51] the impact to the general public becomes extraordinary.

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[49] The effects of AirCell interfering signals on CDMA guard band channels are not considered in this analysis. However, it can be shown that harmful interference can also occur, albeit to a lesser degree, with AirCell signals on CDMA guard band channels, from the results of Phase 1 and 2 tests.

[50] Under current FCC Waiver limitations, up to six channels can be used by AirCell systems, at each base station, allocated as one channel for control data and five channels for voice traffic.

[51] The source of this information is the National Emergency Number Association, available at www.nena.org. In addition, the CTIA reports the number of 911 and emergency distress calls made from wireless phones in year 2001, as 156,000 calls per day, or 108 calls per minute.

Figure 6.4-A Jet Aircraft Flight Profile & Affected Terrestrial Cell Sites, SL45 Antenna, 90% Signal

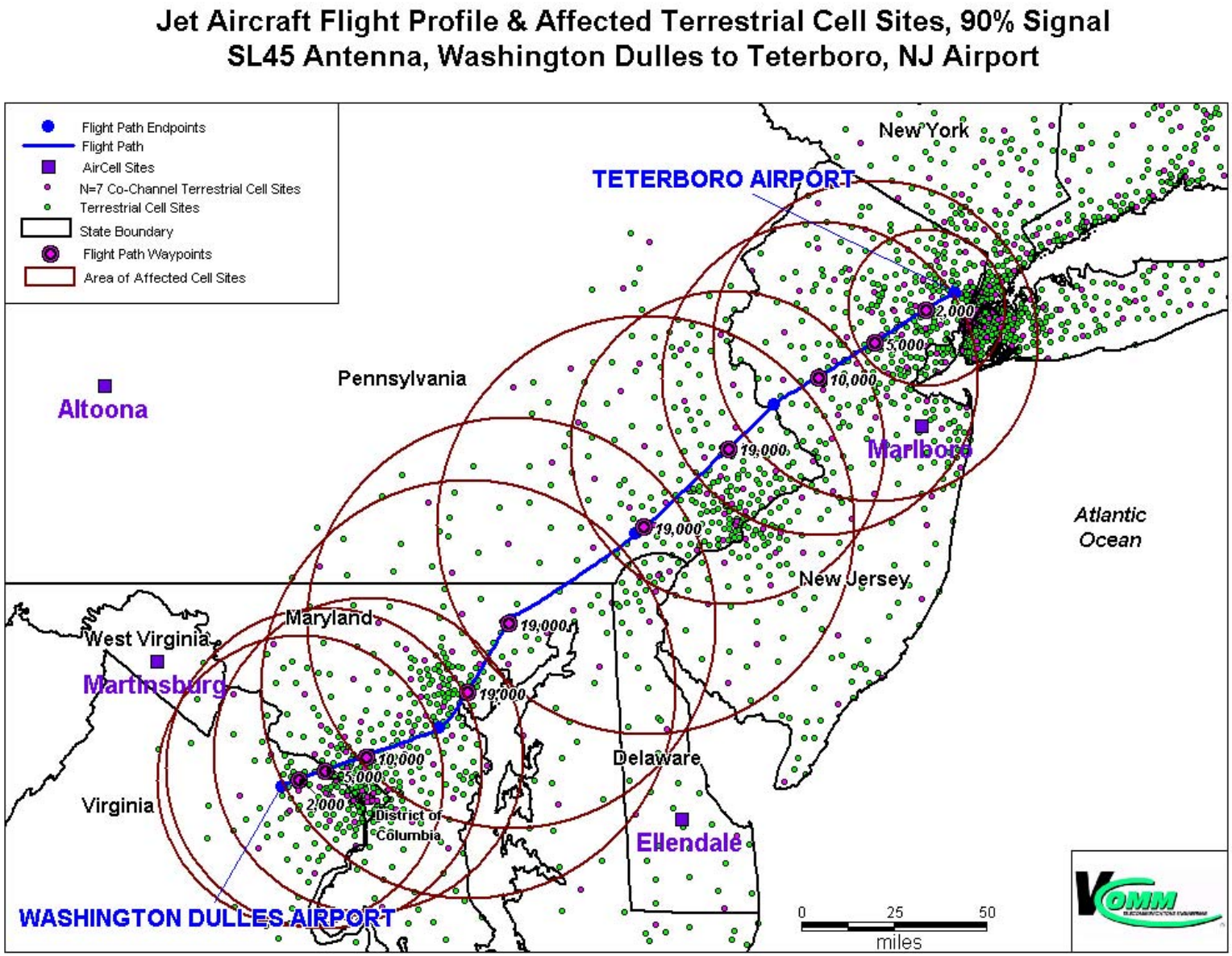
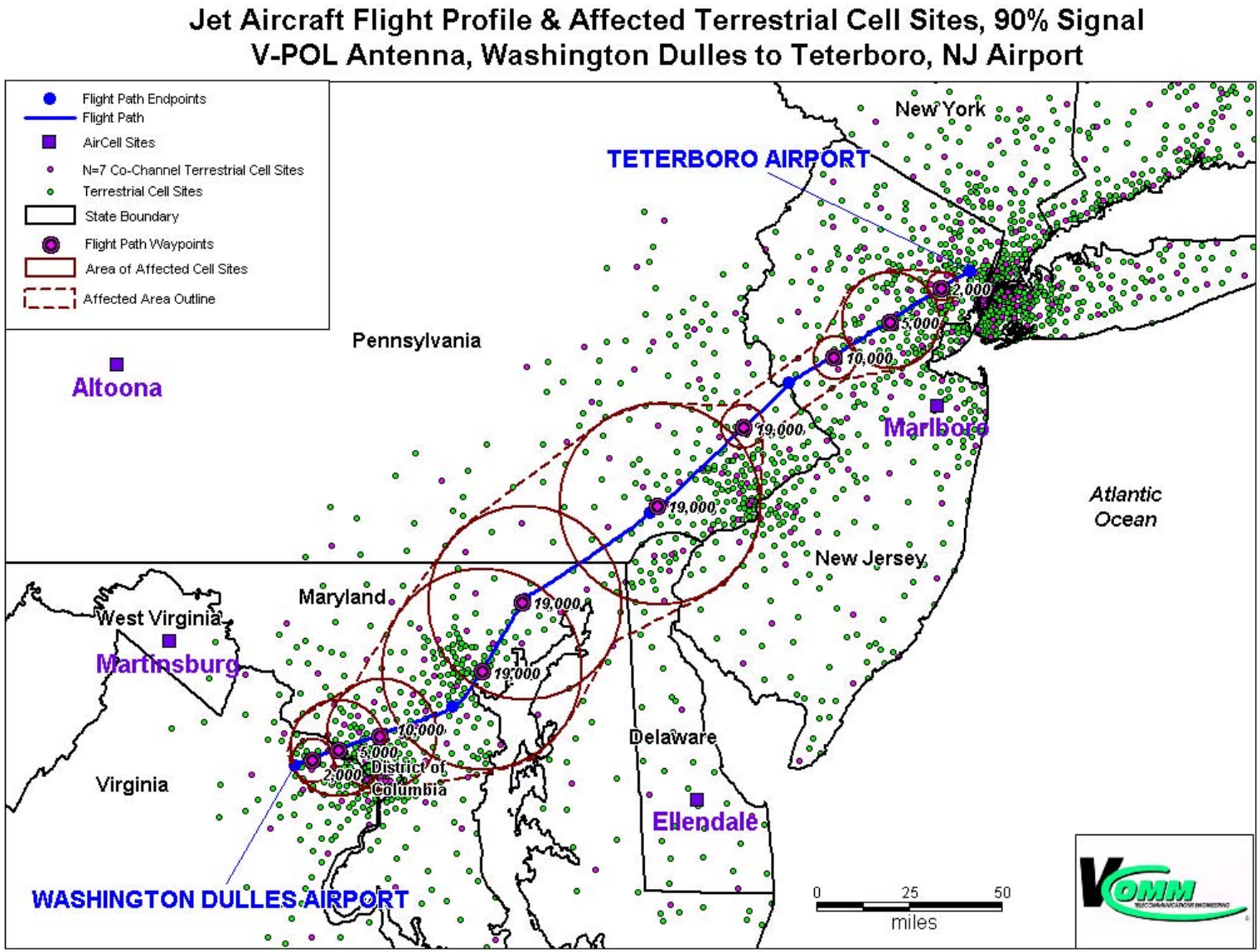


Figure 6.4-B Jet Aircraft Flight Profile & Affected Terrestrial Cell Sites, V-POL Antenna, 90% Signal



7 Analysis of Test Results and System Compatibility Issues

7.1 Analysis of AirCell Compatibility Test Results

As outlined in previous sections of this report, it can be seen that AirCell airborne mobiles can have a detrimental impact on the operation of terrestrial cellular systems. This detrimental impact can be characterized as harmful interference to the terrestrial networks when the airborne units are at a variety of altitudes and transmit power levels. In the FCC's MO&O concerning the AirCell waiver, it provided the definition for "harmful interference" with respect to the compatibility of AirCell's secondary use of cellular spectrum as "serious obstructions, degradations or repeated interruptions of cellular service."[52] As demonstrated in the Case Study, provided in Section 6 herein, the harmful interference affecting the terrestrial cellular network is significant. Serious obstructions, degradations and repeated interruptions to terrestrial cellular service are expected for airborne AirCell units operating along typical flight paths in heavily traveled corridors.

Further, as indicated in the Case Study, a significant number of terrestrial cellular sites will be affected when typical flight paths are flown within major metropolitan areas in the northeast. Specifically, the case study for the cross-polarized (SL45) terrestrial antenna for the 90% signal results identifies approximately 220 AMPS, 220 TDMA, or 1560 CDMA terrestrial cellular sites will experience harmful interference from AirCell airborne units operated along this typical flight path. As indicated in the next section, the cross-polarized antennas are quickly becoming the antennas of choice for many cellular operators, and the FCC has approved the deployment of such antennas within many cellular networks across the nation. Further, for terrestrial cellular networks utilizing vertical-polarized panel antennas (V-POL), it has been identified in the Case Study that approximately 90 AMPS, 90 TDMA, or 650 CDMA terrestrial cell sites will experience harmful interference from AirCell airborne units operated along this typical flight path.

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[52] AirCell, Inc., Memorandum Opinion and Order, FCC 00-188, Appendix ¶ 4 (June 9, 2000). In a subsequent order, the FCC said that in analyzing AirCell's 1997 test data it deemed interference to be "harmful" when it exceeded the -117 dBm interference threshold level used in its analysis by 7 dB or more (i.e., when the AirCell signal is received at a level of -110 dBm or higher), on the ground that interference below this level is "objectionable" and "annoying" but not "harmful." AirCell, Inc., Order on Remand, FCC 02-324, ¶ 22 (Feb. 10, 2003). The interference threshold level used in that analysis is inapplicable here, because it was premised on a minimum acceptable call level of -100 dBm, which is inconsistent with the measured noise levels and call levels in V-Comm's tests. In addition, the FCC's analysis only considered analog terrestrial service. Moreover, it is unclear what the basis is for the FCC's assumption that 7 dB of degradation above the interference threshold level represents the borderline between acceptable and unacceptable interference for purposes of analyzing the 1997 analog data, and in any event that criterion cannot readily be used for analyzing V-Comm's flight test data.

A variety of AirCell signal levels received at terrestrial sites were observed and recorded in Phase 1 tests. These signal levels ranged from -72 dBm in the worst case scenario to -130 dBm in a best case scenario.[53] Signal strengths varied in range from significant enough to cause repetitive dropped calls, reduced system capacity and degraded audio quality, to others that are insignificant and have no measurable effect on cellular system performance. When the impact of terrestrial cellular interference caused by AirCell airborne units is considered in densely populated areas (i.e. Dense Urban, Urban, Suburban), the number of individual calls affected is significant and is anticipated to be as great as 20 per terrestrial CDMA sector, between 3 to 50 per terrestrial TDMA sector, and 1 per terrestrial AMPS sector. The TDMA number is based upon whether or not the AirCell interference is to a voice channel or digital control channel. When the number of affected terrestrial telephone calls per sector are multiplied by the number of affected terrestrial sites, as outlined in the Case Study, the volume of serious obstructions and system degradations is quite large. In fact, as many as 30,000 CDMA, 10,000 TDMA, or 200 AMPS terrestrial calls could be affected by aircraft along the Case Study flight route. If this interference is spread across less densely populated areas, the total number of individual calls affected is expected to be considerably less, however, the interference potential per call would be greater. This is due to larger cell sites, which are more susceptible to interference at lower levels, since they can operate at lower received terrestrial signal levels and still maintain toll quality calls.

7.2 Analysis of Phase 1 Results – Susceptibility of Different Terrestrial Antenna Types

Several different types of terrestrial antennas were utilized in Phase 1 tests. Each of the antennas utilized represent a typical antenna type currently in use today, or contemplated for use by cellular operators around the country. Currently, the most common type of antenna deployed today are Vertically Polarized Panel Type Sector antennas, denoted as V-POL antennas in the Phase 1 tests. The signal strengths received from AirCell airborne units were relatively strong when the aircraft was moving within the horizontal beam width pattern of one of these antennas (i.e. as high as -86 dBm at distances within 4 miles of the victim terrestrial site). If the aircraft was “behind” one of these sector antennas, it is observed that received signal levels dropped off between 3 dB and 10 dB, typically.

Horizontally Polarized (H-POL in report) terrestrial antennas exhibited the highest received signal levels from airborne units, as expected. AirCell uses horizontal polarization in an effort to provide isolation to vertically polarized terrestrial cellular

[53] At the upper end of this received signal range, potential interference from AirCell signals can also affect terrestrial cell sites using adjacent channels, for AMPS & TDMA systems. The potential interference to terrestrial cell sites using adjacent channels is not considered in this report.

systems. Terrestrial cellular systems using horizontally polarized receive antenna systems will achieve 0 dB isolation from the AirCell system.

Cross-polarized antenna systems (SL45 in report) are becoming increasingly popular for use in terrestrial cellular systems. These antenna systems use diagonally polarized (45° angle) elements, and as a result have the ability to receive signals from both the vertical and horizontal polarities at higher signal strengths, as compared with V-POL antennas. These antennas are being utilized by terrestrial cellular operators to address network growth issues while maintaining similar performance to traditional vertically polarized spatial diversity receive antenna systems, with great success. These antennas receive vertically and horizontally polarized signals equivalently, and thereby represent a compatibility issue since AirCell's antenna system isolation is no longer achieved.[54] The AirCell signals received at the SL45 terrestrial antenna were close to the levels measured on the H-POL antenna (within approximately 3-4 dB). This fact is of great concern, since many operators are replacing their vertically polarized antenna systems over the next 12-24 months. In fact, Cingular Wireless is in the process of replacing approximately 45,000 V-POL type antennas with SL45 type antennas over the next 2 years, as approved by the FCC.

Finally, omni-directional whip antennas were also used in testing. These antenna systems exhibited the least reception of airborne signals, likely due to the relatively narrow vertical beam width, slightly lower gain, and vertical polarization of these systems. However, despite these characteristics, received signal strengths from airborne AirCell units, were also at levels that could cause harmful interference to the terrestrial system, in certain situations.

The table below (Table 7.2-A) compares the relative airborne received signal strengths for each type of terrestrial antenna tested.

Table 7.2-A AirCell Signals Received per Terrestrial Antenna Type

Terrestrial Antenna Type	**Relative Level of AirCell Signals Received**	**Typical Difference**
H-POL	Strongest	Reference level
SL45	2nd Strongest	3-4 dB lower than H-POL
V-POL	3rd Strongest	14-15 dB lower than H-POL
OMNI	4th Strongest	15-16 dB lower than H-POL

The standard deviation of this difference is observed between 6 to 7 dB for the vertically polarized antennas and 2 to 3 dB for the slant 45-degree antenna.

[54] Terrestrial cellular systems using Slant-45 polarized antennas receive terrestrial signals at approximately 0 dB to 3 dB lower than equivalent antennas with vertical polarization, due to the polarity of the incoming terrestrial signal. In cases when both the terrestrial and AirCell signals are received at the terrestrial site at a level 3 dB lower, the AirCell signals will exhibit approximately 0 dB isolation from the terrestrial signal levels.

It should be noted that, while aircraft were traveling in the main horizontal beam pattern of terrestrial V-POL antennas, the measured airborne signals were as much as 3 dB greater than terrestrial Omni antennas. Also, the results indicate that the effective front-to-back ratio of the terrestrial V-POL antenna (based upon differences in received airborne signals) varied between 3 dB and 10 dB. The effective front-to-back ratio (based upon differences in received airborne signals) was between 10 dB and 25 dB for H-POL and SL45 terrestrial antennas. These two antennas measured front-to-back ratios were closer to antenna manufacturer specifications due to the ability of these antennas matching the horizontally polarized AirCell airborne transmissions.

In the table below (Table 7.2-B), the commonality of deployment for each of the terrestrial antenna types in today's cellular networks is outlined.

Table 7.2-B Commonality of Terrestrial Antenna Types

Terrestrial Antenna Type	Commonality in Current Systems	Growth in Future Systems	Comments
H-POL	4th	2nd	Popularity increasing due to implementation and market issues
SL45	3rd	1st	Popularity significantly increasing due to implementation and market issues
V-POL	1st	3rd	Most common today in all cellular networks
OMNI	2nd	4th	More common in rural systems in the past.

7.3 Analysis of Phase 2 Results – Observed Interference to the Terrestrial System

The tests performed under Phase 2 of the AirCell Compatibility Test Plan were specifically designed to determine, measure and record any effects of interference caused by AirCell airborne received signal levels as measured in Phase 1 tests. The Phase 2 tests were performed at a suburban terrestrial cellular site with an approximate coverage radius of 1.5 miles. There are many suburban sites in the northeastern portion of the United States with a similar coverage area and traffic profile. It was intended, as per the site selection process outlined in the AirCell Compatibility Test Plan, that this site would represent a typical suburban site for purposes of the test. However, there are other suburban cell sites in the region serving a coverage radius greater than 1.5 miles, which would exhibit different results due to transmitting distance and path loss considerations on the reverse link (mobile to site link). For example, it is

expected that a 3 mile radius terrestrial site would have greater path loss factors, signals would be received at the site at lower levels, thereby increasing its susceptibility to interference from AirCell airborne units.

Each technology tested at this suburban site exhibited various levels of harmful interference from AirCell airborne units, measured however, with different performance metrics.[55]

When testing terrestrial analog (AMPS) technology, decreases in the carrier to interference (C/I) ratio exhibited a decrease in MOS (Mean Opinion Score), or call quality and ultimately resulted in dropped calls. A reduction in C/I was measured with equivalent received AirCell signals as low as -123 dBm, and affected the average MOS audio quality of the terrestrial suburban test cell at signal levels in the -114 dBm range. It should be noted that "larger" suburban cells, as well as rural and quiet rural cells can expect to see significant impact at the lower end of the range, i.e. closer to -123 dBm, since they serve customers with increased path loss and receive signals at lower levels. The same is also true for in-building users within the cell's coverage footprint, and users at the cell edge.

The TDMA performance metrics which exhibited an adverse effect when receiving equivalent airborne signals include C/I, blocked & dropped calls, Bit Error Rate (BER), Mean Opinion Score (MOS) and Minutes of Use (MOU). As equivalent airborne received signals were injected into the suburban test site, decreases in the C/I ratio exhibited an increase in BER, a decrease in MOS, and a decrease in MOU. A reduction in C/I was measured with equivalent AirCell signals as low as -120 dBm, with increases in BER at -117 dBm, and significant decreases in MOS and MOU (capacity to serve customers) at signal levels in the -114 dBm range, for the terrestrial suburban test site. It should be noted that "larger" suburban cells, as well as rural and quiet rural cells can expect to see significant impact at the lower end of the range, i.e. closer to -120 dBm, since they serve customers with increased path loss and receive signals at lower levels. The same is also true for in-building users within the cell's coverage footprint, and users at the cell edge.

The CDMA technology performance metrics analyzed in Phase 2 were Mobile Transmit Power, blocked and dropped calls, overflowed calls, and Minutes of Use (MOU). Call quality, capacity and coverage in a CDMA network are a function of the noise level within the system. In the Phase 2 tests, equivalent AirCell signals were injected into a CDMA site thereby modeling the "noise" anticipated from an AirCell unit. At received airborne signal levels as low as -120 dBm, a 1.6 dB increase in Mobile Transmit Power was observed. In addition, when equivalent AirCell signals are received at the -114 dBm level, greater than 3 dB increase in Mobile Transmit Power was measured.

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[55] The terrestrial performance metrics are described in section 4.1.1. In addition to these metrics, affects to terrestrial cellular portable phone battery life can occur in some situations. Digital terrestrial cellular systems (ie. TDMA & CDMA), instructing terrestrial mobiles to power-up to meet performance thresholds in the presence of interference, may experience affects of decreasing available battery life for terrestrial mobile phones.

Increases in CDMA mobile transmit power is due to the increased operating cell site noise floor, which is caused by the injected AirCell signals. This represents harmful interference, and will cause a reduction of coverage, capacity and call quality for many terrestrial CDMA cell sites and calls. It should be noted that "larger" suburban cells, as well as rural and quiet rural cells can expect to see significant impact at the -120 dBm level, since they serve customers with increased path loss and at higher mobile transmit power levels. The same is also true for in-building users within the cell's coverage footprint, and users at the cell edge. The CDMA test results provided in this section are for 1 signal injected on the CDMA carrier during normal day-time operation, on a live cellular network.

7.4 Other Terrestrial Cellular Sites, Not Tested

The site tested in Phase 2 of the AirCell Compatibility Test Plan was a suburban site in the Trenton, NJ MSA cellular system. This site, as previously described, was considered a suitable suburban site candidate with an approximate coverage radius of 1.5 miles, i.e. the distance between the test site and its adjacent neighbors is approximately 3 miles. The venue tested is considered to be a fairly typical suburban area located just outside the state capital, Trenton, NJ. While this site was chosen to represent suburban sites, other areas which are also considered suburban, but within somewhat different demographic density, have "suburban sites" that have a coverage radius which is greater than 1.5 miles, that is up to a 3 mile radius. Conversely, the cellular operators in this region also operate "suburban sites" with radii of less than 1.5 miles, or as small as approximately 0.75 miles. Therefore, while this site was chosen as a representative "typical" suburban site, others sites may have greater susceptibility to interference from airborne AirCell units, but most suburban sites should exhibit similar properties.

Other site classifications which were not tested in Phase 2 interference tests include Dense Urban, Urban, Rural and Quiet Rural. While somewhat similar results are expected to these site classifications, each of the site classifications may exhibit slightly different susceptibility to interference from airborne AirCell units, some less and some more.

Dense Urban and Urban sites are generally located very close together. While this close proximity to other sites allows the terrestrial cellular mobiles to be generally close to a serving site, these areas typically have high building density which creates a high path loss environment. In situations where the terrestrial subscriber unit is outdoors and nearby a dense urban or urban site, it is anticipated that the susceptibility to interference from airborne AirCell units in relatively low. However, when transmitting from within a building, which is fairly common in these venues, received signal strength back at the terrestrial site can be very low due to path loss considerations. This low received signal strength, when overlaid with an airborne AirCell signal strength as measured in the Phase 1 tests, is expected to exhibit a susceptibility close to that in the suburban tests of Phase 2, provided the site's operating noise floor is not significantly elevated.

Rural and Quiet Rural sites are another classification that was not tested in Phase 2 interference tests. The traffic on these sites is generally much lower than the other classifications. For this reason, the coverage area for these sites is generally much greater, at times exceeding 10 miles. Almost all subscriber units sold today are low power hand held units. This low power unit, coupled with a large coverage radius, significantly increases the susceptibility to interference from an airborne AirCell unit. These sites were not tested as they were expected to exhibit the worst case conditions with a great likelihood of significant harmful interference on an individual call basis. While the volumes of calls are relatively low in these areas, the impact of interference from an AirCell unit is expected to be relatively high. The worst case scenario would be a terrestrial cellular subscriber making an emergency assistance or 911 call, on a dark highway, at the edge of a rural site at a received terrestrial signal of -105 to -110 dBm, and dropping that call due to an airborne AirCell unit transmitting at maximum power flying within a 40 mile radius of the rural site. The two signals would be competing for the same spectrum, and unfortunately, the terrestrial subscribers would lose. Within the Philadelphia/NJ market alone, there are many highways that have terrestrial cellular coverage from sites that are approximately 10-15 miles apart (with rural characteristics). These highways include the NJ Turnpike from exits 1-3; I-295, exits 1-15; U.S. 40 through Salem County, NJ (headed to Atlantic City). Each one of these sections of highway falls within the coverage area of the Marlboro AirCell cell site.

7.5 Other Terrestrial Cellular Technologies, Not Tested

Several other terrestrial cellular technologies were not tested in Phase 2 interference testing. These technologies represent the current and future initiatives of cellular operators necessary to meet both market demands and FCC requirements. These technological initiatives include 3G (3rd generation) voice and data (for all operators), GSM/GPRS (the current 3G migration path for TDMA operators), and E911 location based technologies (required for all operators), CDPD (an earlier generation wireless data technology still in place, and used by many local police departments), and Tower Mounted Low Noise Amplifiers (TMA). Each of these technologies is expected to have a different set of issues and corresponding susceptibility to airborne AirCell interference. It is imperative that these technologies are tested to develop an understanding of the compatibility of the AirCell air-to-ground system with each terrestrial market offering. Some of the issues that are expected to come to the forefront very quickly are related to GSM/GPRS, and 3G (voice and data).

The current 3G migration path for TDMA carriers is to overlay GSM and GPRS technology on the existing TDMA networks. In order to accomplish this task, “tighter” frequency reuse schemes are anticipated for deployment. It is envisioned that the TDMA reuse schemes (approximately N=7, or, the same frequencies are used every 7 cells) will be reduced to N=5. This “tighter” frequency reuse scheme will be deployed for quite some time, while the networks and subscribers transition from a TDMA base to a GSM base. A “tight” reuse scheme will be required for these networks to co-exist

within the cellular operators' radio spectrum. Eventually, the networks and subscriber base will transition to a fully GSM network. During this transition, TDMA operators will be using their channels more often in market. When AirCell calls occupy assigned channels, this translates to more cells that are co-channel with the AirCell call and an increased likelihood of interference events occurring. This will result in a larger number of affected calls than predicted with a frequency reuse of N=7, used in the case study.

TMA technology is currently in use primarily in some rural and quiet rural areas. These amplifiers, when affixed atop the tower near the receive antennas, typically allow for a 1-3 dB improvement in the system noise figure over operation without a TMA. These TMAs are used to help balance the forward and reverse links for terrestrial cell sites. This technology works very well in low noise environments. The TMA allows a cellular customer to be served with lower signal and noise levels, and further distances from the serving terrestrial cell site. This improvement can translate into a one mile or more improvement in a rural cell's coverage area. It is expected that the introduction of airborne AirCell transmissions in these environments, would reduce the effectiveness of this technology, as the TMA amplifies all received signals, including interfering signals. This translates to an increase noise floor of the rural terrestrial site, and reduced coverage and performance of the cellular system.

It is anticipated that third generation (3G) CDMA networks will be more susceptible to interference from airborne AirCell units, than 2G CDMA (IS95) cellular systems. In 3G systems, the advances in technology enable the system to utilize signal at lower power levels and higher modulation schemes, which results in signals that are more susceptible to increases in the noise floor than 2G systems.

As mentioned previously, each of the current and future technologies, 3G, GPRS, EDGE, GSM, E911 Phase 2 location, CDPD, etc. all utilize different air interfaces, standards, performance criteria, and voice-coders than the technologies included in this test plan. Also, bandwidth requirements, power control, frequency use, and channel assignments varies for each of these technologies. Further, C/I system requirements, reverse link topologies, data transmission schemes and methods of use (e.g., triangulation from multiple sites at lower signal levels for E911 Phase 2 location) differ per technology such that substantial compatibility testing is required to determine the effects of AirCell airborne interference on these terrestrial initiatives (and mandates).

This represents a continued burden for terrestrial operators to test and evaluate the AirCell system compatibility issues, as newer and more advance technologies are integrated into the terrestrial cellular system.

7.6 AirCell Cell Site Parameters and Optimization

The results of Phase 1 flight tests with DPC enabled of the "AirCell Compatibility Test" are based upon the operation, configuration, and optimization of the serving AirCell Marlboro cell site and its parameter settings. All AirCell cell sites are optimized by

AirCell on a site by site basis. V-COMM had the opportunity to review AirCell's optimization levels and parameter settings at three other nearby (rural) AirCell sites, Altoona, PA, Owego, NY, and Martinsburg, WV. Upon review of these other AirCell sites, it was determined that there were differences in the average received power versus the AirCell (suburban) Marlboro site. For example, utilizing calibrated test equipment, V-COMM measured the average received signal strengths (center of "power box") approximately 2 dB higher at the Altoona, PA site versus the Marlboro, NJ site. Therefore, airborne AirCell phones used within the coverage area of the rural Altoona site are approximately 2 dB stronger than the suburban Marlboro site. Consequently, AirCell signals received at terrestrial cells in those areas will be 2 dB higher than that which were measured for the Marlboro test results outlined herein. Furthermore, the maximum airborne mobile transmit power allowed at the rural Altoona AirCell site is 4 dB higher than allowed at the suburban Marlboro AirCell site (i.e., maximum DPC at Altoona was 2, whereas Marlboro was 3). This further emphasizes the likelihood of increased levels of received terrestrial interference than that which is outlined herein.

Therefore, the differences in configuration and optimization of individual AirCell sites directly affects the potential for increased terrestrial interference. Terrestrial operators, the primary users of this cellular spectrum, should be afforded the opportunity to access all AirCell site parameters that affect airborne mobile unit transmit power levels, so both the carriers and FCC can evaluate the true worst case scenario.

7.7 Terrestrial AMPS Noise Floor Study

In conjunction with the tests conducted under Phase 1 & 2 of the AirCell Compatibility Test Plan, V-COMM conducted separate tests designed to determine the operating "noise floor" for terrestrial AMPS cellular networks in the same study area as the AirCell Compatibility Test Plan was conducted. This "AMPS Noise Floor Study" is attached hereto as Appendix 9.17. The final conclusion of the noise floor study was that the respective median operating "noise floors" at the terrestrial cell sites in Dense Urban, Urban, Suburban, and Rural areas are -123 dBm, -126 dBm, -127 dBm and -127dBm, on average. The respective noise floor and performance figures for both TDMA and CDMA networks are expected to perform at similar levels. When these noise floor figures are considered, the interference impact from airborne AirCell units becomes very significant. For example, in an AMPS or TDMA network, assuming a required 17 dB C/I ratio for toll-quality calls, the ability to maintain quality calls in the -110 dBm (terrestrial received signal strength measured at the cell site) on a suburban site is achieved and exists.[56] Further, dense urban calls operating with significant path loss attenuation, are still maintainable, with toll-quality, at -106 dBm received signal strength (again relative to the terrestrial mobile uplink). When considering that signal strengths measured from airborne AirCell units in Phase 1 tests were significantly higher than the aforementioned

[56] The suburban terrestrial test site used in Phase 2 tests exhibited a considerable percentage of terrestrial customer signals at the –110 dBm level, as depicted in graphs in appendix section 9.9.

-110 and -106 dBm levels in many cases, and as high as -72 dBm, it can be determined that the AirCell air-to-ground system will cause harmful interference to terrestrial cellular systems. Further, it has the ability to cause serious obstructions, degradations and repeated interruptions to terrestrial cellular service.

7.8 Analysis of Case Study Results

V-COMM developed tests under Phase 1 and 2 of the AirCell Compatibility Test in order to provide "baseline" data which can be used to accurately predict the potential for interference between AirCell's air-to-ground cellular network and the existing terrestrial cellular networks. Outlined within section 6 of this document is a fully detailed "Case Study" in which V-COMM modeled typical flights and air traffic within the study area to predict the actual impact, if any, that an airborne AirCell unit would have on terrestrial cellular subscribers.

First of all, flight data was researched from a variety of sources, including FAA sources, NY & NJ Port Authority, and by interviewing local commercial and general aviation pilots. The flight route was chosen to be a typical and heavily traveled route in the northeastern United States.

Second, the Phase 1 and Phase 2 results were correlated to the attributes of the flight route to ascertain the impact of potential interference to the terrestrial cellular system. These attributes included typical altitudes, climbing and descending rates, airspeed figures for different types of aircraft typically flying these routes and approach/landing patterns. As can be seen in Table 6.4-C, the number of affected terrestrial sites and telephone calls is quite large.

The results of this Case Study, for the cross-polarized terrestrial antenna, indicate that as many as 223 AMPS sites would be affected by airborne AirCell units flying this typical flight route. The number of TDMA cells affected is also 223, while the number of CDMA cells affected is 1564, since the CDMA frequency reuse factor is N=1, which means all CDMA terrestrial sites within receiving range of the transmitting aircraft are affected.

The predicted impact of interference to terrestrial cellular networks, from airborne AirCell units, ranges from poor call quality to dropped calls, reduced network capacity, and a decreased overall ability to access and utilize the terrestrial cellular network.

The aforementioned tests of Phase 1 and 2 of the AirCell Compatibility Test Plan were developed and executed to provide a data set that could be extrapolated into a typical situation in the northeast, e.g., the Case Study herein. This data could also be extrapolated to other parts of the country where the terrestrial networks are similar. This method of data collection and analysis was chosen over a purely statistical model in order to develop an accurate view of the severity and potential for harmful interference to the terrestrial cellular network.

The benefits of utilizing the measured test data / case study methodology verses a purely statistical analysis allows the following:

1. A method that shows the effects to the entire terrestrial cellular network for a typical flight. It shows the *number* of affected terrestrial cell sites and telephone calls with harmful interference.
2. A model that has the ability to capture the interference impact to hundreds of terrestrial cell sites, the effects of which, would be otherwise impractical to collect similar measurements at these sites, with the quantity of test equipment and personnel required.
3. A model that utilizes a real world scenario that occurs over one hundred times a day, every day though out the year. (Actually, this flight occurs 113 times per day on average, for the scheduled commercial flights alone. Other general aviation and non-scheduled charter flights will add to this occurrence.)
4. Utilizes empirical data rather than statistical assumptions to truly depict the compatibility issues of these co-existing technologies.
5. Avoids the pitfalls of using incorrect or marginal assumptions for statistical probability analyses.
6. Avoids the pitfalls of statistical "dilution" of the impact to thousands of terrestrial cellular subscribers spread across the country.
7. Utilizes measured data that can be reproduced and/or utilized in future studies, technological evolutions, etc. for either the airborne or terrestrial technologies.
8. Represents an accurate view of the compatibility of the AirCell and terrestrial cellular system in heavily populated areas. In these areas the terrestrial cellular system has very high use of cell phone traffic, and the airspace "above" has very high use of airplane traffic.

7.9 AMPS compatibility with Co-Channel & Co-SAT Interference

AirCell AMPS systems co-existing with terrestrial cellular AMPS systems have additional compatibility issues in co-channel and co-SAT situations, as described below. (SAT is the Supervisory Audio Tone that is used on AMPS voice channels to maintain telephone calls.) The terrestrial cellular system has a total of 3 unique SAT frequencies, and all three SAT are used throughout the cellular system. This could affect the performance of the terrestrial cellular system for the AMPS customers, or the digital customers that overflow to AMPS, or roam on AMPS channels outside their home network areas in AMPS mode. These effects were not tested in the Phase 2 tests, but are explained below.

Since AirCell systems operate using AMPS technology for its cell sites and mobiles, terrestrial cellular systems can misinterpret AirCell signals for its customers using AMPS

technology. Both signals look the same, using standard AMPS voice channels and Supervisory Audio Tones (SAT). This is true for the cell-to-mobile forward link and the mobile-to-cell reverse link. Terrestrial cell sites and terrestrial mobiles have the potential for being "fooled" by AirCell signals, in this manner, providing the signals are received above levels which terrestrial calls operate, and are co-channel and co-SAT. For this reason, Phase 2 AMPS tests utilize signal generators using a different AMPS SAT than the site is using. This prevents the cell site from misinterpreting the injected signal, from the desired signal. If the same SAT is used, the call would remain on the cell site, even at very high injected interference levels, with the cell site interpreting the signal generator's signal as the desired signal, which is not the case.

With AirCell and terrestrial systems using the same AMPS technology, it is possible for the following events to occur, providing the AirCell signal is received by the terrestrial system above the levels that terrestrial calls operate. They are explained in the two categories below, for the terrestrial cell site forward and reverse link.

1. Cell Site Forward-Link System Compatibility Issues (cell to mobile)
   A. AirCell mobile phone "switches-over" to terrestrial system, after responding to a terrestrial system handoff command on the forward voice channel. In this case, the AirCell mobile would be handed off to another party (probably ending the call sometime thereafter), and would result in a dropped call. However, the cellular system is "fooled" in this case, and would record this event as a successful call. Also after this handoff occurs, the AirCell mobile would most likely be powered up to its 75 mwatts maximum level with typical terrestrial system target received signal power thresholds.
   B. AirCell mobile responds to the terrestrial system "power control" commands on the same forward-link voice channel that are intended for a terrestrial caller, and inadvertently increases power, which increases the likelihood of interference to the terrestrial system.

2. Cell Site Reverse-Link System Compatibility Issues (mobile to cell)
   A. Terrestrial cell sites receiving the "Call End" command from the AirCell mobile on the same reverse voice channel, can respond by ending the terrestrial call. This results in a dropped terrestrial call, without the cellular system's knowledge that the call was dropped.
   B. Terrestrial cell sites receiving a "3-Way Call" command from the AirCell mobile on the same reverse voice channel, can respond by initializing this new call on the voice channel of the terrestrial system. In this event, the terrestrial caller would hear a different party and eventually hang-up if the interference persists. In this event, the outcome is a failure of service or a dropped call, again without the terrestrial cellular system's knowledge.
   C. Terrestrial cellular system can experience full "RF capture" of the AirCell mobile on the co-channel, co-SAT reverse voice channel. In this case, the terrestrial landline party would hear the AirCell mobile party, and is assumed to end the call

thereafter, unless the interference disappears. Again, in this case, the cellular system would not know the call was lost.

D. Terrestrial system can experience impairments with “locate measurements” and handoff performance. Terrestrial analog cellular systems use reverse link voice channel measurements at Neighbor Cell Sites for handoff selection (up to 20 Neighbors per sector). Impairments to these measurements can caused delayed or misinterpreted handoffs, which can lead to dropped calls. Co-channel and co-SAT locate measurements for handoffs, can result in mistaken handoffs and dropped calls for terrestrial mobiles. Co-channel and different SAT locate measurements for handoffs, can mask and delay handoffs from occurring, which can result in a deterioration in call quality and dropped calls for terrestrial mobiles. This system compatibility issue has the potential to impact the performance of many cell sites, since it can affect not only the co-channel cell site, but also all of its neighbors (up to 20 other cell sites).

Again, the potential for these events occurring, depend on the AirCell signal levels received by terrestrial cell sites and terrestrial mobiles in relation to normal levels which calls operate. The effects listed in this section were not measured in Phase 2 AMPS tests. In these cases, any interference or dropped calls that occur as a result of co-channel co-SAT AirCell interference, would not be registered on the cellular system as dropped calls. To the cellular system, they would appear as successful calls, and would rely on the terrestrial or landline party to terminate the mishandled AMPS call. With the AMPS standard having a total of three SATs, the probability of an interference event that is co-channel and co-SAT is 1 in 3, or 33.3%.

7.10 Phase 2 Interference Test Data Analysis with Trend Lines

Analysis of Phase 2 test data is also be useful with fitting trend lines to the data. This process of reviewing the data with the expectation that performance degradation must monotonically increase with interference levels, increases the statistical significance of the results.

In analyzing this data, the trend lines appear consistent with the test data results and expectations, which adds a level of confidence and certainty to the results. In addition, to analyze test repeatability, V-COMM has conducted secondary drive tests for a sample of tests, and the results of these duplicated tests are consistent with the original test data points, which adds further confidence and certainty to the results.

The results of the Phase 2 drive tests are expected to be repeatable. For all drive tests, the localized test parameters, test environment, and test conditions in the field were

maintained as consistent as possible to ensure the drive test results are repeatable, and can be directly compared.[57]

In addition, it can be observed in some cases with increased levels of interference the variability of effects also increase, with some metrics showing different effects than others and having dynamic relationships to each other. When reviewing the results of only one metric, we do not see the entire picture of what is happening to the performance of the cell site. For this reason, it is important to review the results of all the metrics involved to determine the full effects of the interference.

Sample graphs are included at the end of this section with trend lines added to results of the Phase 2 test data. The "Least Squares" method was used for fitting the trend lines to the data. The trend lines are depicted in relevant "areas of interest" on the graphs below.

[57] The same drive route and operating conditions were utilized in all drive tests. Other test parameters were maintained consistent across the drive tests as well; these are fully explained in V-COMM's "AirCell Compatibility Test Plan" document, which is submitted in this proceeding.

Figure 7.10-A Phase 2 Test Results with Trend Line: AMPS Mean Opinion Audio Quality Score

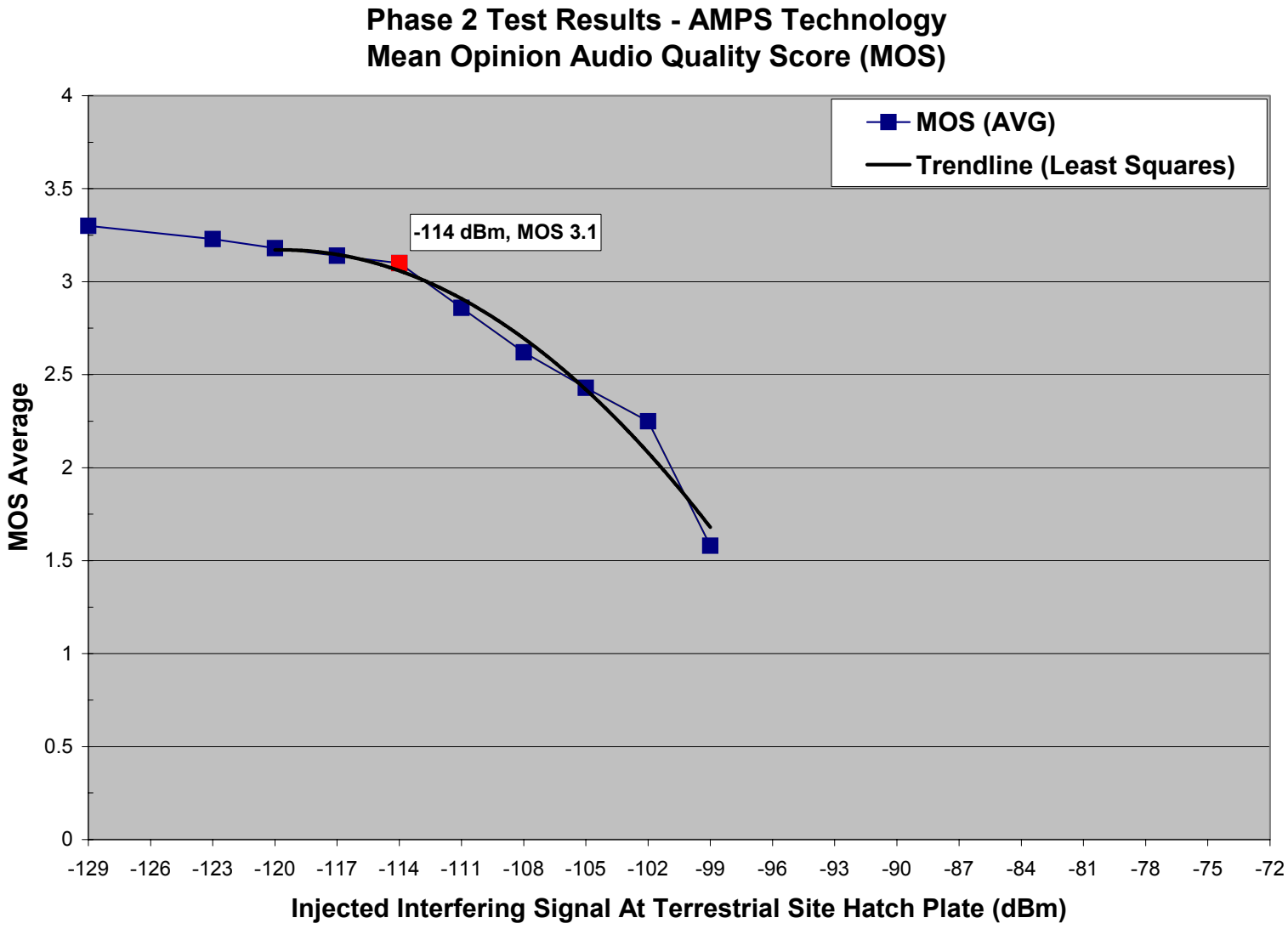


Figure 7.10-B Phase 2 Test Results with Trend Line: AMPS Minutes of Use

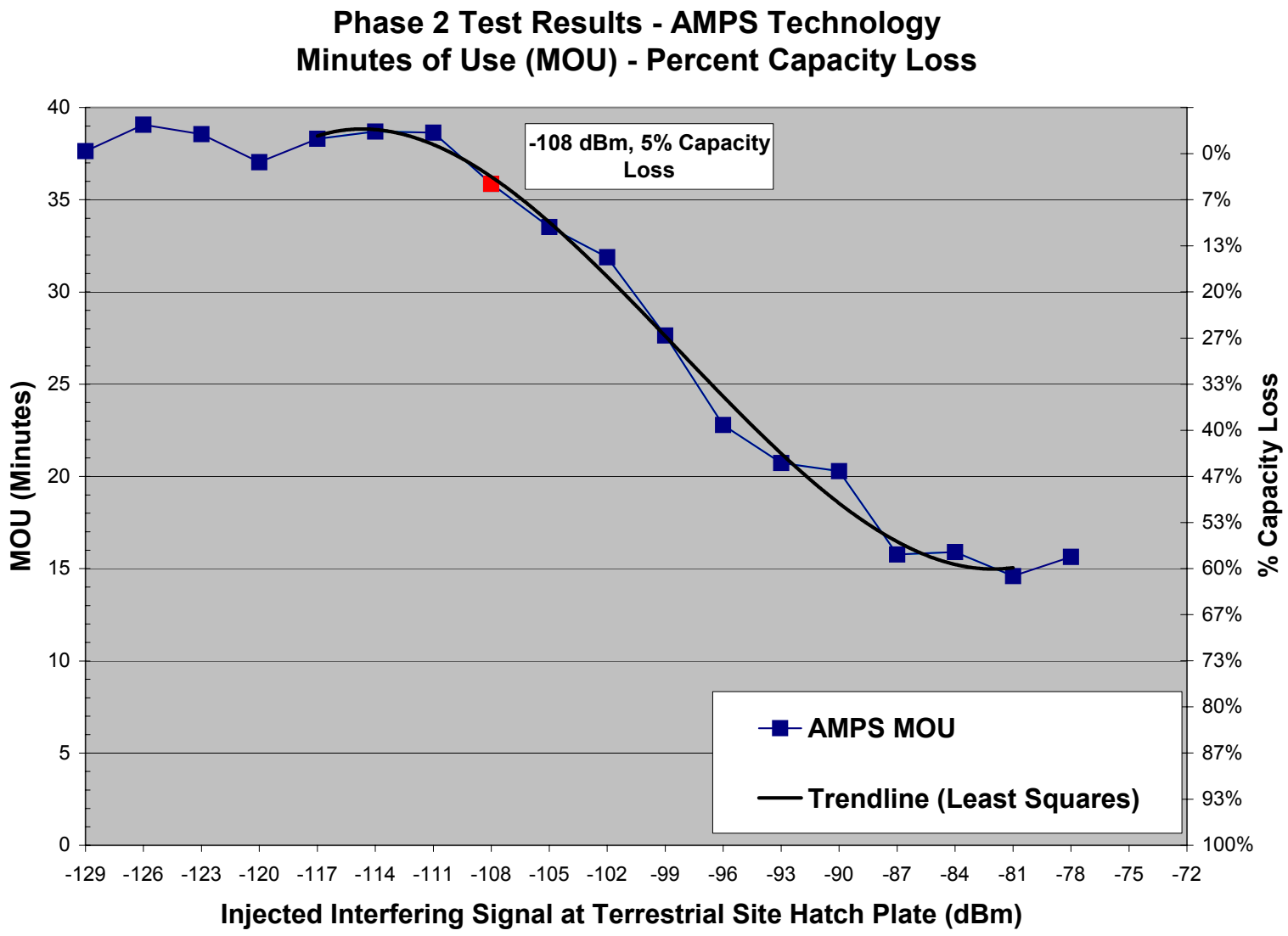


Figure 7.10-C Phase 2 Test Results with Trend Line: AMPS Blocked and Dropped Call Percentage

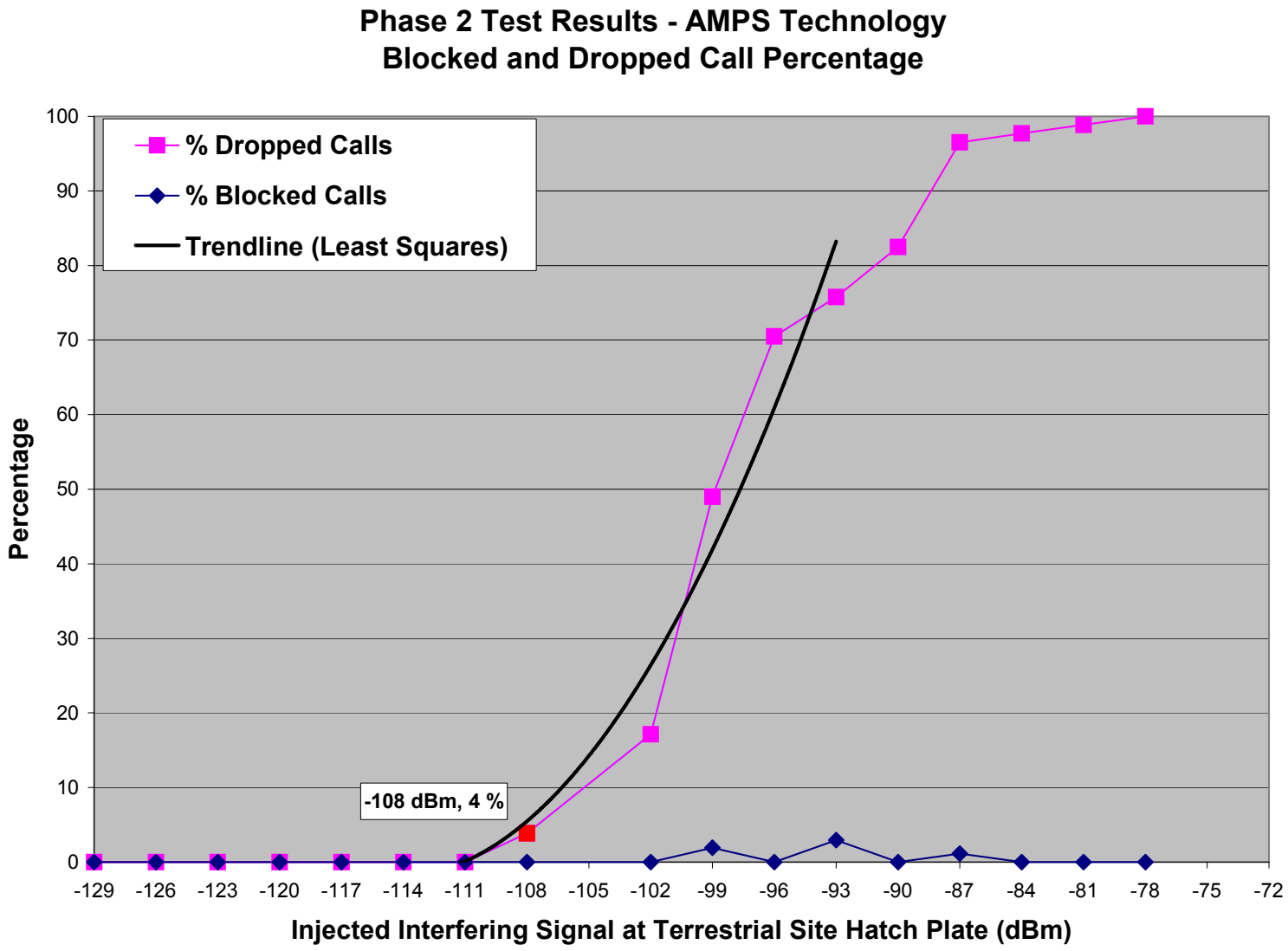


Figure 7.10-D Phase 2 Test Results with Trend Line: TDMA Bit Error Rate Percentage

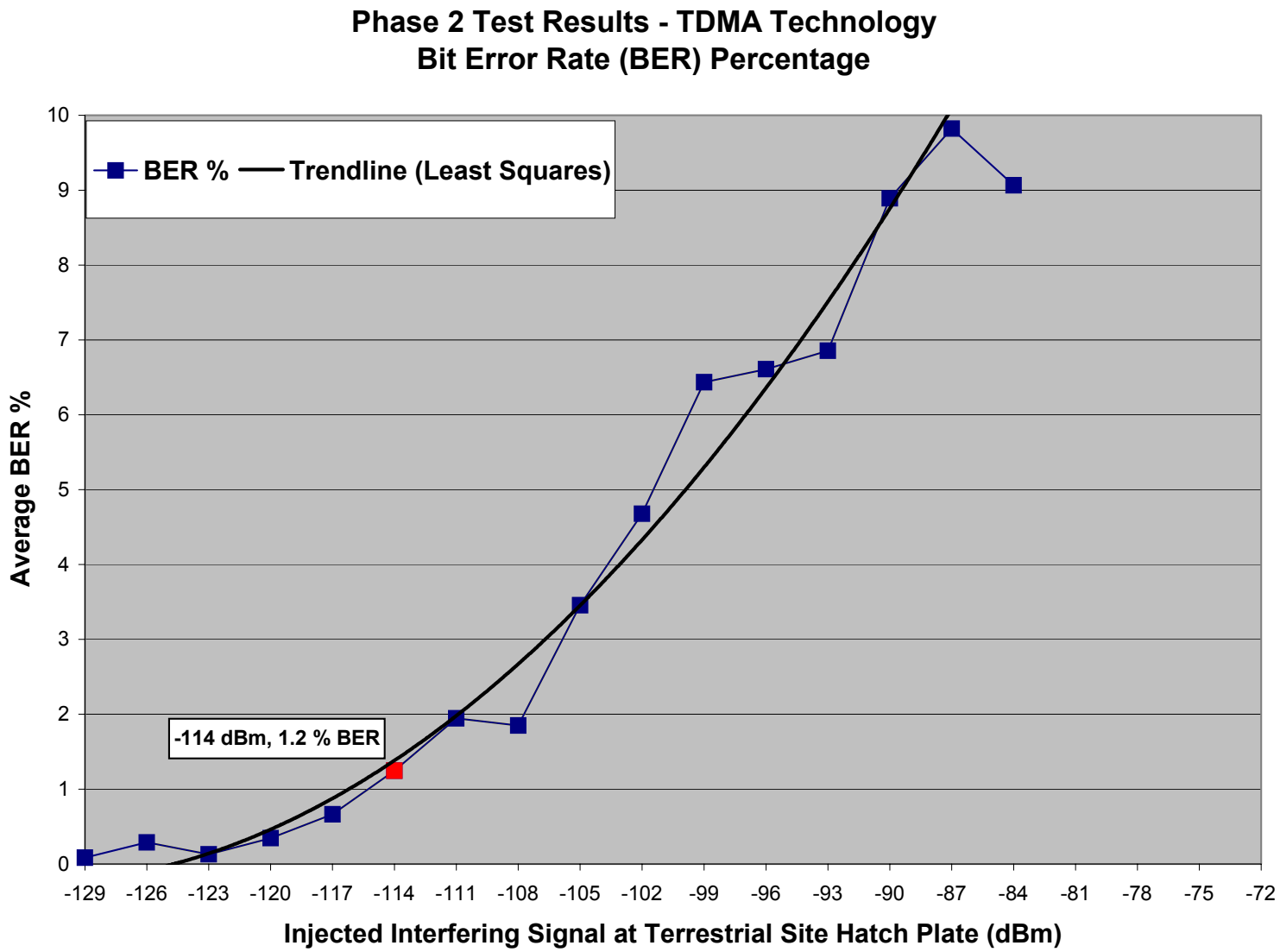


Figure 7.10-E Phase 2 Test Results with Trend Line: TDMA Minutes of Use

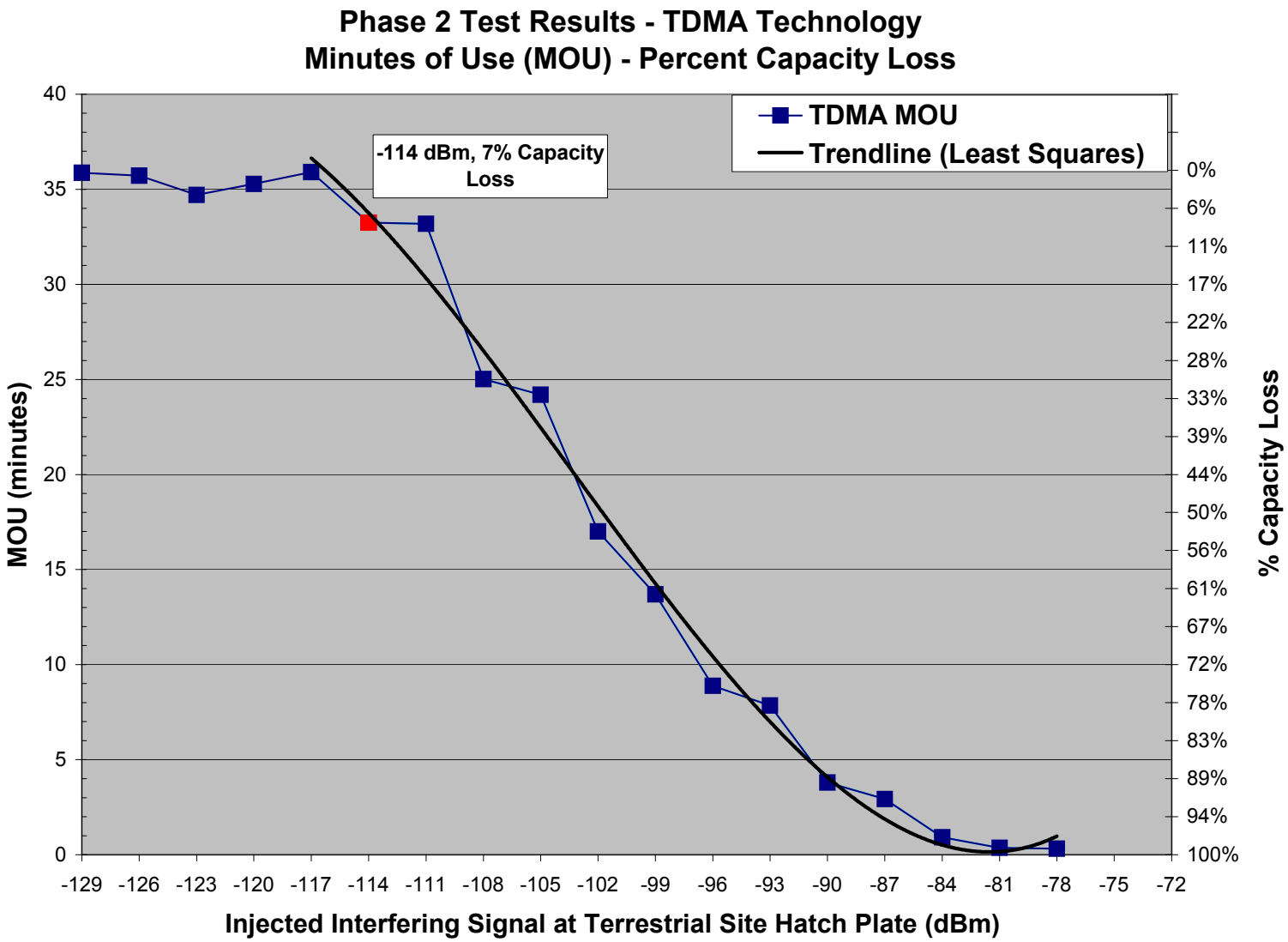


Figure 7.10-F Phase 2 Test Results with Trend Line: TDMA Blocked and Dropped Call Percentage

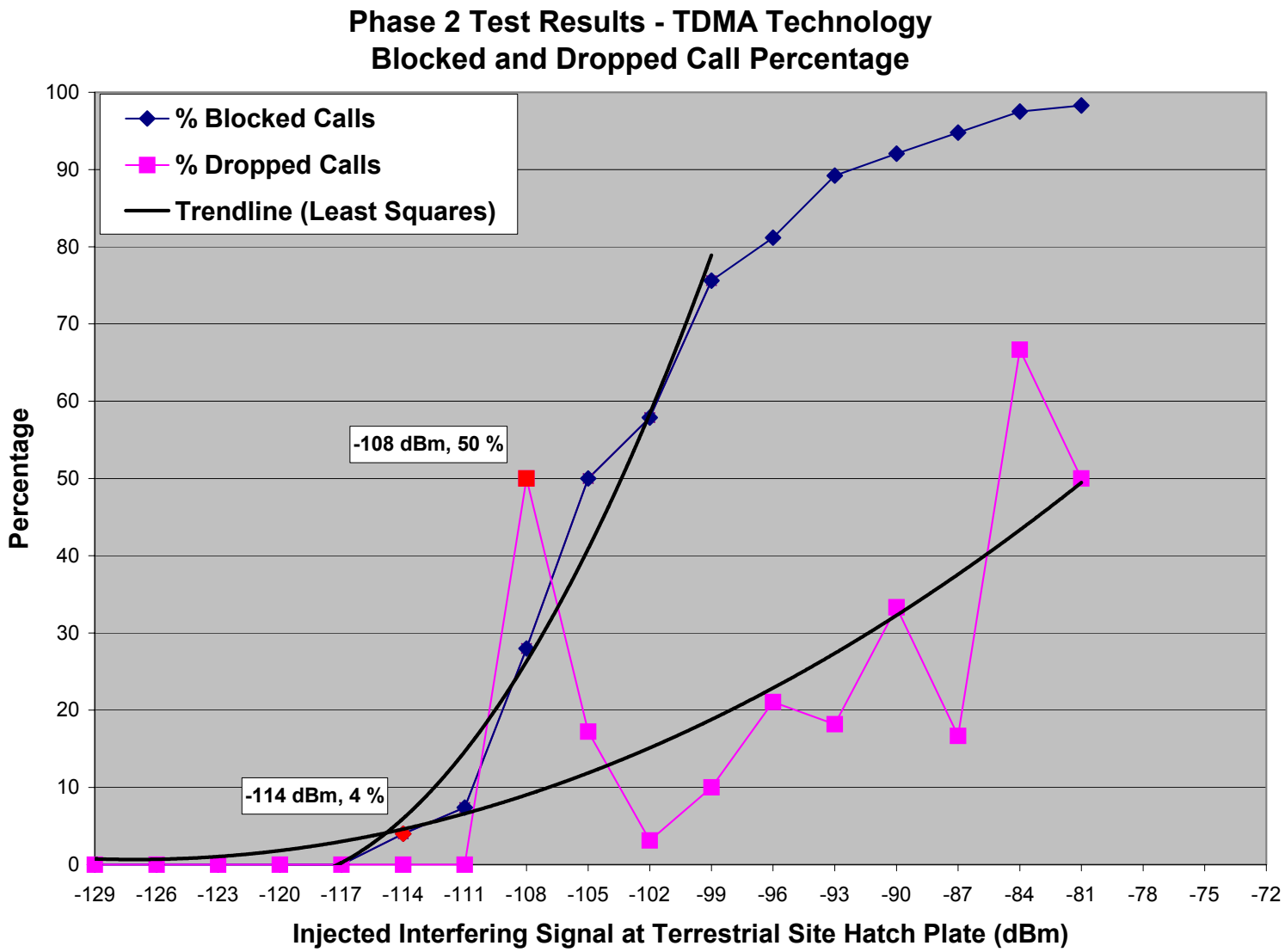


Figure 7.10-G Phase 2 Test Results with Trend Line: CDMA Mobile Transmit Power, 1 Injected Signal on Carrier

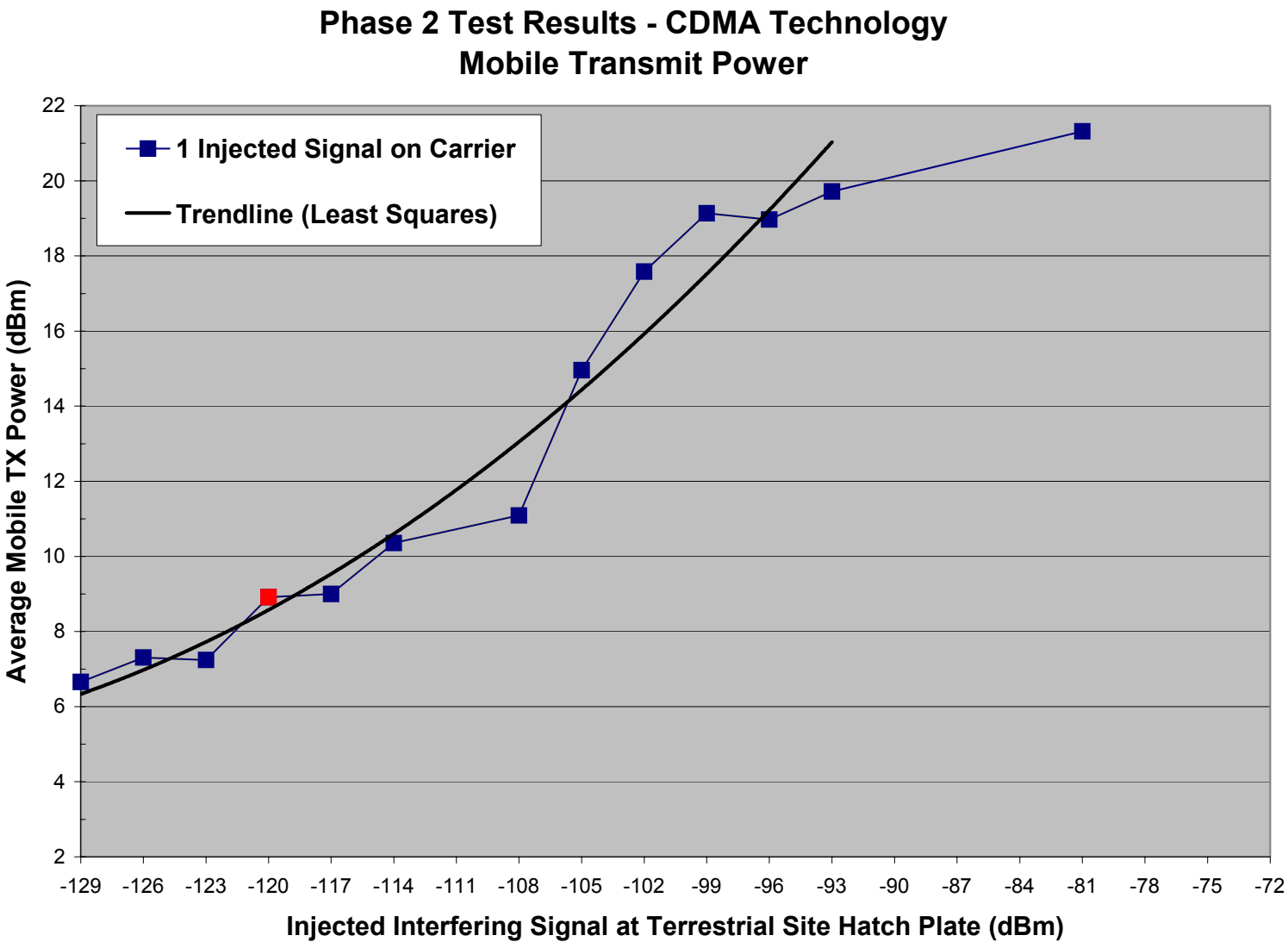


Figure 7.10-H Phase 2 Test Results with Trend Line: CDMA Blocks, Drops & Overflow, 1 Injected Signal on Carrier

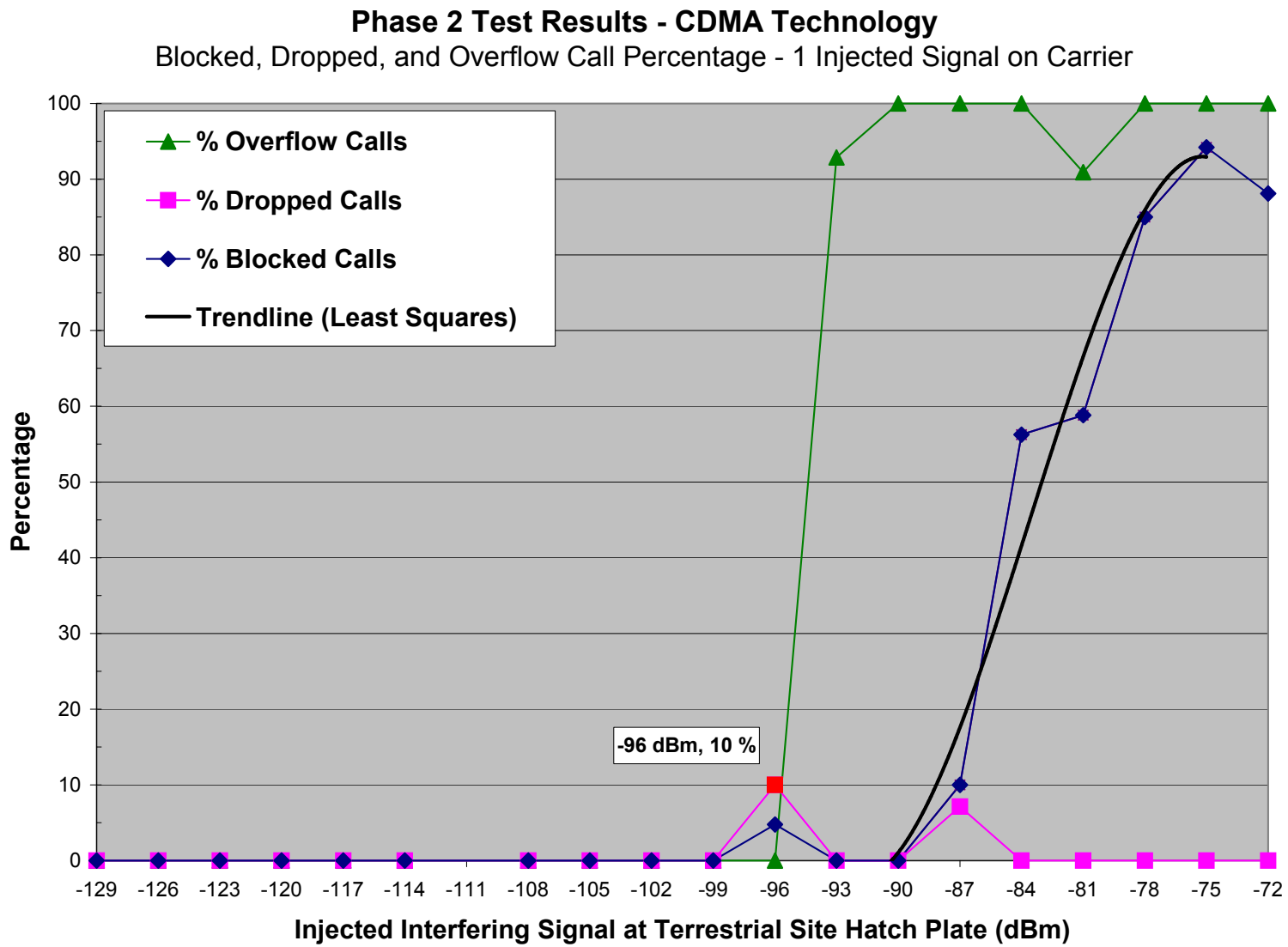
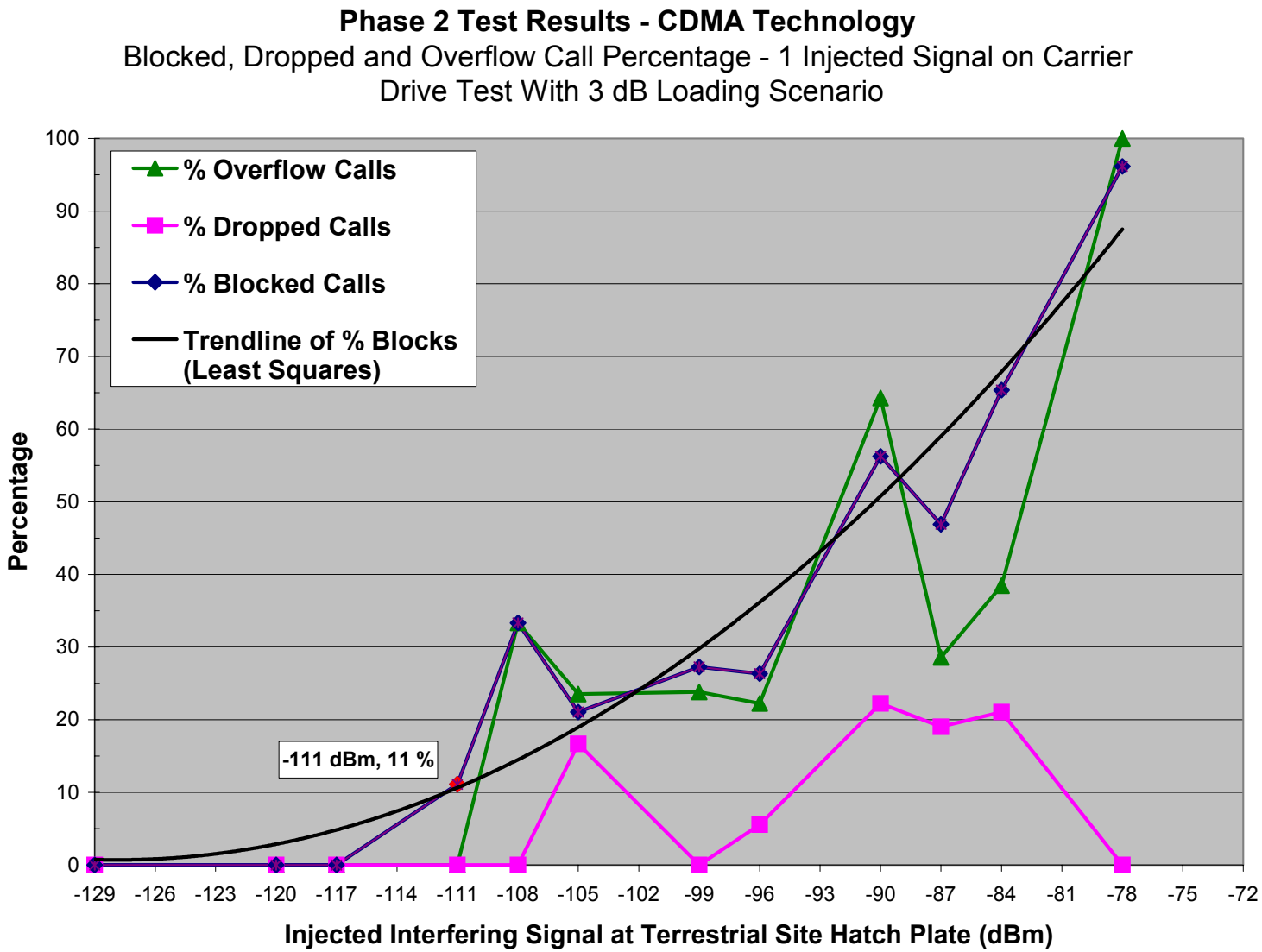


Figure 7.10-I Phase 2 Test Results with Trend Line: CDMA Blocks & Drops, 1 Injected Signal on Carrier, 3 dB Loading



8 Conclusion

The purpose of tests performed by V-COMM and outlined herein, was to study AirCell's air-to-ground cellular telephony system and its compatibility with existing terrestrial cellular telephony systems. Ultimately, the goal of the tests was to determine whether or not the airborne cellular system, as a secondary service used within the cellular radio spectrum, would cause harmful interference, as defined by the FCC, to terrestrial cellular systems, the primary service used within the cellular radio spectrum.

Testing included a comprehensive number of actual flight tests, from which the airborne signal strength data was measured and recorded. Also, interference tests were performed which included 3 technologies, AMPS, TDMA and CDMA. These interference tests were performed for a typical suburban terrestrial site in the northeastern United States. Finally, a comprehensive noise floor study was performed for AMPS technology.

Results from the aforementioned tests indicated that "harmful interference" can occur from AirCell airborne units to terrestrial cellular sites. The received airborne interfering signals (from Phase 1 of testing) were measured as high as -72 dBm and as low as -130 dBm with many signals falling in the -90 dBm to -100 dBm range. Phase 2 interference tests indicated a significant increase in adverse terrestrial performance metrics such as dropped calls, blocked calls, low MOS (audio quality) and reduced system capacity. A Case Study was developed to better understand the potential extent of this harmful interference in a highly populated corridor, such as the northeastern United States. Results of the Case Study indicate that as few as 200 and as many as 1500 terrestrial cell sites can be adversely affected by a single typical flight (from Washington, D.C. to the New York metro area). Further, between 200 and 30,000 individual terrestrial subscribers/calls can be affected by this same flight. This flight is the most popular flight route in the northeast and on average is flown over 100 times per business day. Therefore, the repetitiveness of this harmful interference is significant

As previously mentioned, three terrestrial technologies were tested, AMPS, TDMA and CDMA. Future and newer technologies, such as 3G, E911 Phase 2 location, GSM, GPRS, EDGE, etc., need to be tested as well. Based upon the results of the tests performed, it cannot be assumed that the results will be similar to those presented herein. In fact, it is anticipated to be worse than what is outlined herein, due to lower operating powers and differences in air interface specifications.

Finally, we conclude that AirCell's secondary use of cellular radio spectrum, causes harmful interference to the primary use by terrestrial cellular operators. While this harmful interference does not happen in all cases, when it does occur, it causes serious obstructions as demonstrated by increased system blocking, reduced system capacities, performance degradations as demonstrated by reduced MOS (audio quality), and repeated interruptions as demonstrated in the Case Study for typical flights in a densely populated corridor. Therefore, AirCell's system operation does not meet

the conditions of the FCC waiver permitting air-to-ground service as a secondary use of cellular spectrum.