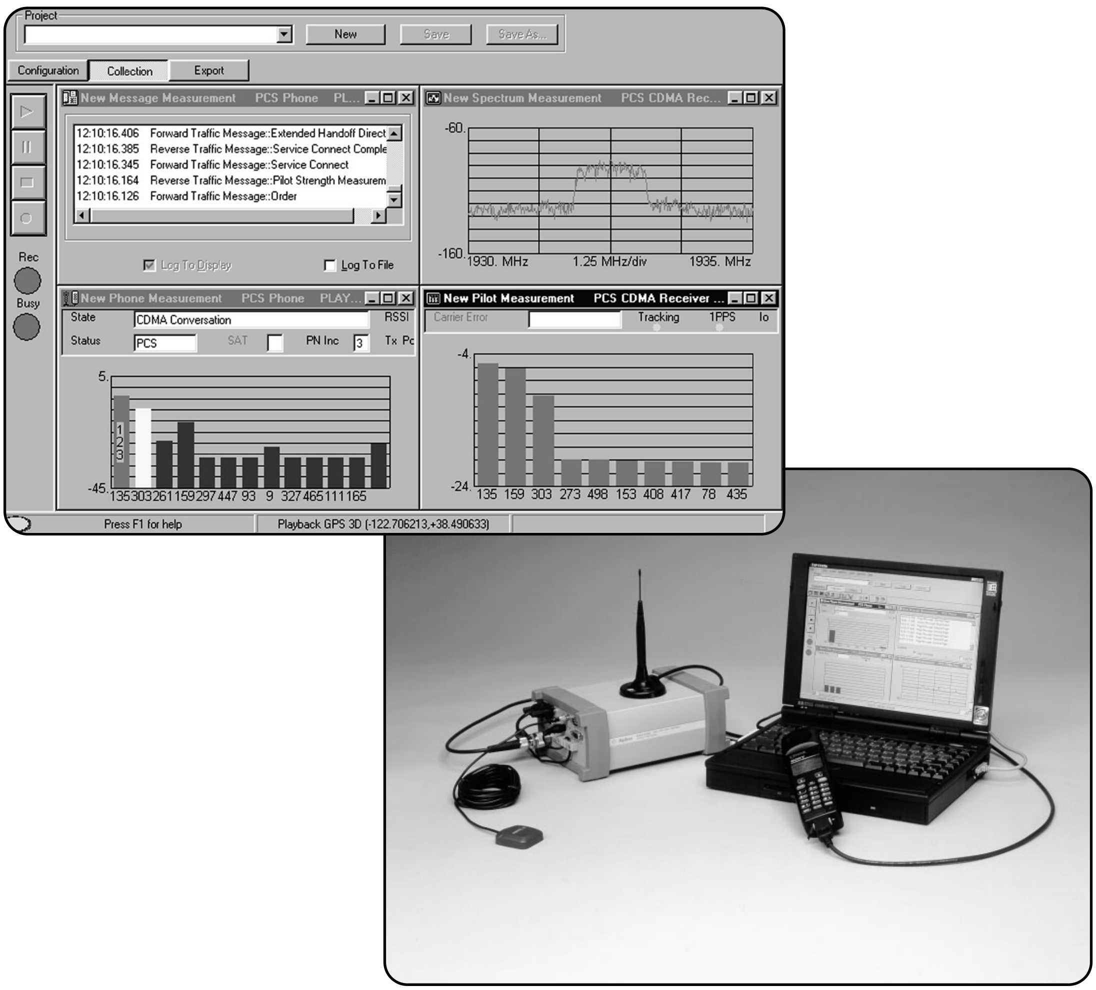
Agilent Technologies
CDMA Drive-Test Systems
Product Note



Agilent Technologies
Innovating the HP Way

Section 1: Introduction

The growth and expansion of cellular and PCS networks continues at a rapid pace throughout the world. To retain existing customers and attract new customers, wireless service providers must maintain the highest quality of service throughout their networks. Drive-testing remains an essential part of the network life cycle, as an effective means for continually optimizing network performance to maintain customer satisfaction and reduce subscriber churn. This product note provides a detailed overview of how the Agilent Technologies drive-test tools can help optimize your CDMA-based cellular and PCS networks. These tools allow you to turn-up networks faster, reduce optimization time, and improve network quality of service. Drive-test tools include both those required for collecting data as a function of location and those that are used to post-process the collected data for final analysis.

The E7473A drive-test solutions are used for collecting measurement data over a CDMA air interface. The optimum solution combines network-independent RF measurements using an Agilent digital receiver with traditional phone-based measurements. A typical collection system includes a digital RF receiver, a phone, a PC, a GPS receiver and antennas. This integrated drive-test approach, with its built-in automatic alarms, alerts you immediately to the potential network problems. Not only does it tell you "what" the symptom of the problem is, but it also tells you "why" the problem is present. Once the data is collected, the E7480A post-processing software is used to quickly analyze the data to help you find solutions to the problems uncovered by the E7473A drive-test collection system.

Agilent drive-test collection and post-processing solutions

Figure 1 shows how the E7473A drive-test system and the E7480A post-processing software can quickly and easily identify a missing neighbor situation. This is often the cause of dropped call problems that take significant time to solve with traditional drive-test tools.

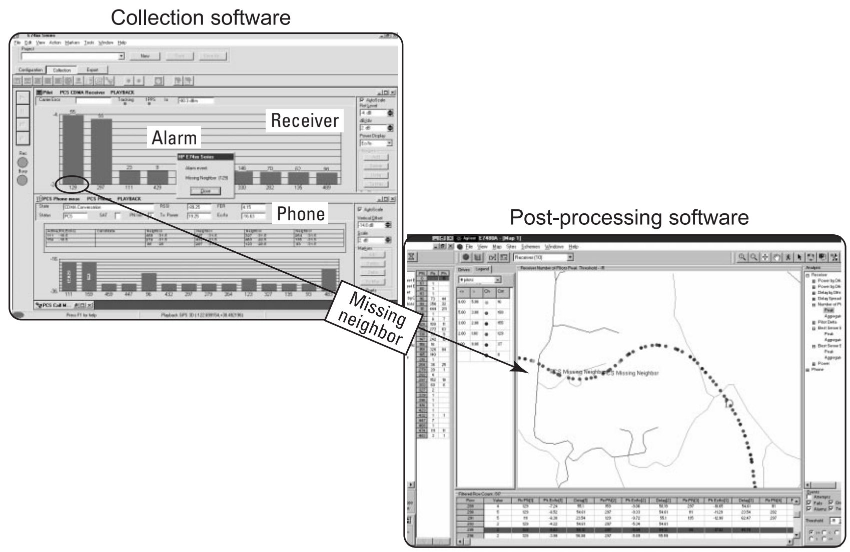


Figure 1. Integrated receiver and phone-based drive-test collection tool combined with post-processing software to identify missing neighbor network problem. Automatic alarms identify PN offset of missing neighbor pilot signal

Benefits of CDMA drive-test solutions

This product note follows a step-by-step approach, with each section building on the previous section. This will give you a clear picture of the benefits that the drive-test solutions can provide for each case study.

The integrated E7473A drive-test collection solution includes both phone-based and receiver-based tools. When combined with the E7480A post-processing software, the drive-test system provides a comprehensive solution for optimization applications:

- Integrated, simultaneous data collection—using both a phone and a digital receiver—reduces the amount of time it takes to optimize networks
- Phone determines service coverage problems to reveal "what" the symptom is, and the digital receiver provides network-independent RF coverage to disclose "why" the service coverage problems are occurring
- Requires a single laptop computer for phone-based and receiver-based measurements, saving space and money
- System combines the measurement data into a single database for fast and comprehensive comparisons and eliminates the need to drive the same route twice
- Pilot scanning, CW power, channel power, and built-in spectrum analysis are all in one compact, portable digital receiver package
- System includes automatic alarm capabilities to alert operator of RF or messaging impairments
- One GPS receiver, common to both the phone and receiver, is required for precise comparisons of measurements taken at the same geographic location
- Portable receiver, laptop PC, and phone comprise a compact system for rapid deployment and transport; no rack mounting required as with larger alternatives
- Solution is scaleable—from one phone or one receiver up to four phones and four receivers
- Fast equipment setups using "auto-configure" facilitate drive-testing right away
- Solution-directed post-processing minimizes the time required to eliminate network performance problems

These benefits are explained in more detail throughout this document.

Who should read this product note?

This product note is for engineers and technicians in RF engineering or network performance departments who are responsible for drive-testing and optimizing CDMA networks. Companies that include such positions include wireless service providers (or operators), network equipment manufacturers of base station infrastructure and/or mobile handsets, and engineering consultants.

This product note is intended to provide a good understanding of how the Agilent collection and post-processing drive-test tools work and what benefits they provide.

If you are already familiar with CDMA concepts and network optimization, you may want to jump ahead to explore the unique measurement capabilities provided by the Agilent phone-based and receiver-based drive-test tools and post-processing software. Sections 2 and 3 are useful for readers new to wireless network optimization and CDMA concepts. The grayed selections in the following table indicate the sections that may be more useful to readers who are already familiar with these concepts.

Section 2: Network Optimization Overview

Network optimization goals

Tools for network optimization are required to solve a variety of problems. The optimization problems faced by a network equipment manufacturer, a wireless service provider, and a consultant are quite similar. However, the reasons for network optimization may vary depending on the customer category. For example, there are some cases where network equipment manufacturers may not receive full payment until their infrastructure is completely installed, tested, and signed off by the wireless service provider. Therefore, it is important to employ drive-test tools that will optimize the network as quickly as possible with the least amount of re-driving.

Primary goals of wireless service providers are to rapidly acquire new customers and to maintain the highest level of customer satisfaction for existing subscribers. Maintaining high levels of customer satisfaction is the best way to minimize churn, which occurs when subscribers become dissatisfied with their current service providers and switch to one of the competitors. Numerous customer surveys indicate that call quality and coverage area are important to subscribers. Drive-testing provides one of the best ways to optimize the network to obtain the best RF coverage and call quality.

Call quality is defined in this product note to include the following conditions: minimization of dropped calls, blocked calls, and FER (frame erasure rate). These terms are explained in more detail later. For simplicity and consistency throughout this document, the term blocked call will be used instead of access failure or failed origination.

RF coverage is related to call quality. In its broadest view, RF coverage refers to whether a mobile phone is receiving enough RF power to set up a call. Poor coverage generally occurs outside advertised coverage areas, but can occur at network boundaries. More importantly, coverage holes within specified network boundaries often result in problems like dropped calls. Measurement terms like Ec, Io, and Ec/Io will be discussed to characterize RF coverage.

Several case studies are examined to show how the Agilent drive-test tools can help maximize the effectiveness of drive time to solve common optimization problems. For example, RF coverage, pilot pollution, missing neighbor, and phone search window problems are addressed.

Optimization process

This section discusses what drive-testing is and why it is important. There are a number of applications for drive-testing in the life cycle of a wireless network, as shown in figure 2. (This discussion assumes that band clearing has already been performed.)

Prior to installation of the base stations, it is first necessary to perform site evaluation measurements to determine an appropriate location for the base stations. This generally consists of transmitting a CW (continuous wave or unmodulated) signal from a candidate site and measuring it with a receiver such as the one found in the Agilent drive-test systems. Next, initial optimization and verification is performed to take a first-pass look at the RF coverage when the modulated CDMA carrier is turned on.

The next step is the acceptance testing phase, after which the network is handed over from the network equipment manufacturer to the wireless service provider and a sign-off process is completed. The acceptance criteria rely on data collected from drive-testing the network. Once the wireless service provider starts commercial service, ongoing optimization and troubleshooting are continually performed during the life of the network as new cell sites are added for increased capacity or additional geographic coverage. Changes in the propagation paths continually occur, including the addition of new buildings, growth of trees, changing foliage conditions, and equipment deterioration. Moreover, as more subscribers are added and channel traffic increases, CDMA networks need to be re-optimized to account for increased levels of interference caused by the added traffic. (See explanation of Io in Section 3.) In addition, cell breathing caused by varying wireless traffic usage throughout the day requires ongoing network optimization to ensure adequate channel capacity. (Cell breathing is explained further on page 11.) Drive-testing is an excellent way to assist the service provider by measuring RF coverage and interference that affects overall network capacity.

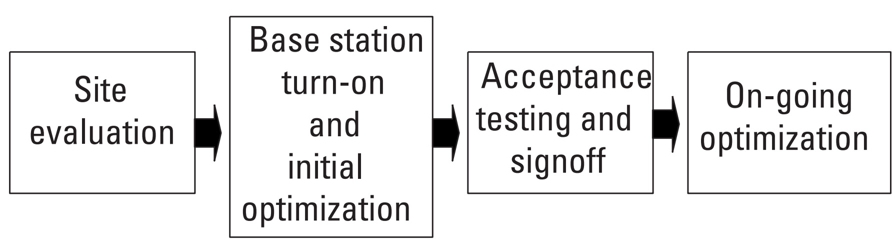


Figure 2. Life cycle of network, showing where drive-testing is needed

Optimization is an important step in the life cycle of a wireless network. An overview of the optimization process is illustrated in figure 3. Drive-testing is the first step in the process, with the goal of collecting measurement data as a function of location. Once the data has been collected over the desired RF coverage area, the data is output to a post-processing software tool such as the E7480A. Engineers can use the post-processing and collection tools to identify the causes of potential RF coverage or interference problems and analyze how these problems can be solved. Once the problems, causes, and solutions are identified, steps are performed to solve the problem.

Figure 3 illustrates that optimization is an ongoing process. The goal is to improve quality of service, retain existing subscribers, and attract new ones while continually expanding the network.

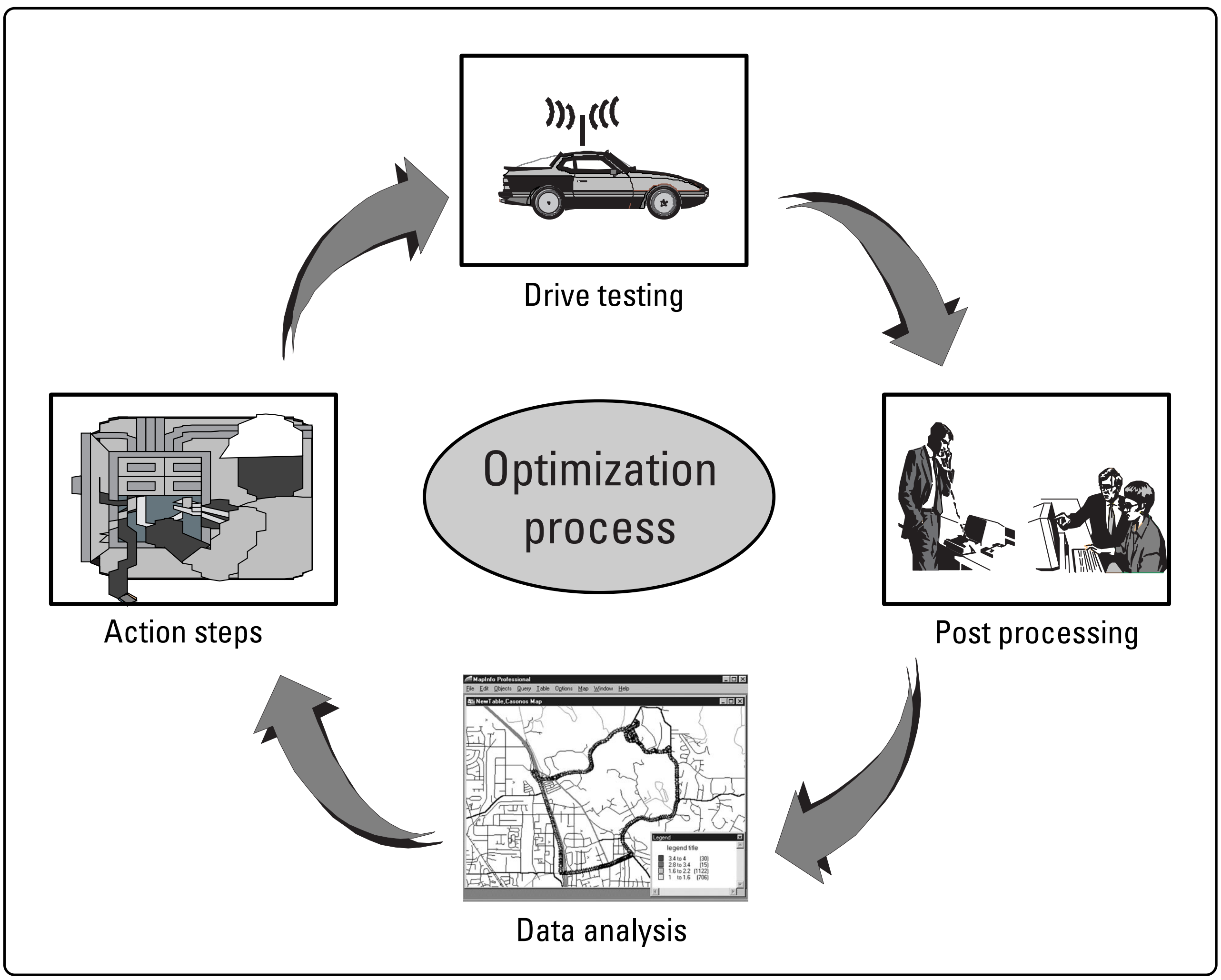


Figure 3. Optimization process begins with drive-testing, moves to post-processing, requires data analysis, and finally action steps are taken to correct the problems. Drive-testing is performed again to verify that the action steps were effective.

Drive-test overview

This section describes the basic concepts of drive-testing. Both network equipment manufacturers and wireless service providers perform drive-testing. Wireless service providers need to optimize their networks as new cell sites are added, new buildings constructed, or other conditions change. Drive-testing allows them to perform this optimization on an ongoing basis. Traditionally, CDMA drive-testing is performed using a phone connected to a portable computer. Cellular and PCS subscribers view the performance of their service on the basis of the network coverage or the call quality. The drive-test tool uses a phone to re-create the problems that a subscriber is experiencing. For example, if a subscriber's call is dropped while operating in a moving vehicle in a particular location, the drive-test should be able to duplicate this problem. Other examples of subscriber complaints include blocked calls (access failures), poor voice quality, and lack of significant coverage. The drive-test system makes these measurements, stores the data in the computer database, and stamps the data as a function of time and location. FER, or frame erasure rate, is a measurement performed by the phone to provide an indication of link quality. Figure 4 shows the E7473A phone-based drive-test system with optional laptop computer and customer-supplied CDMA phone. (Refer to the E7473A configuration guide to ensure that the correct options are ordered. The literature number is provided at the end of this document.) The drive-test system is placed in a vehicle and driven throughout the wireless service provider's network coverage area. Refer to figure 5.

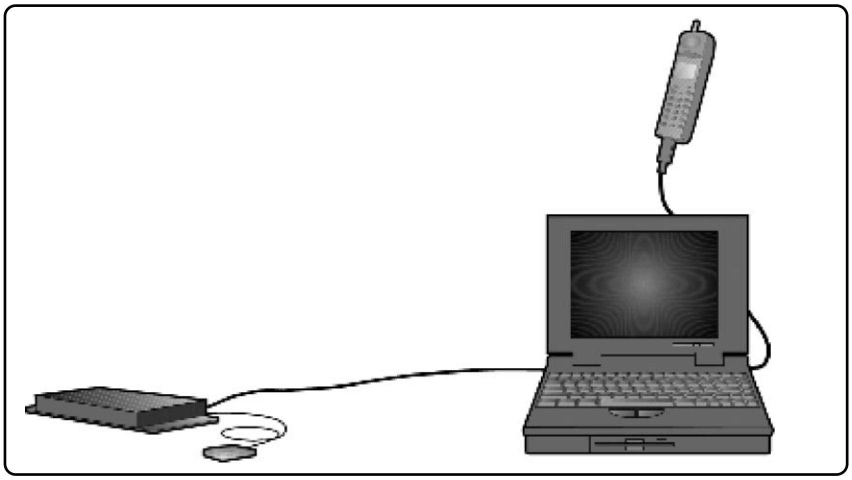


Figure 4. Typical phone-based drive-test collection tool. E7473A phone-based system is shown here with optional GPS receiver and antenna, optional laptop PC, and customer-supplied CDMA phone.

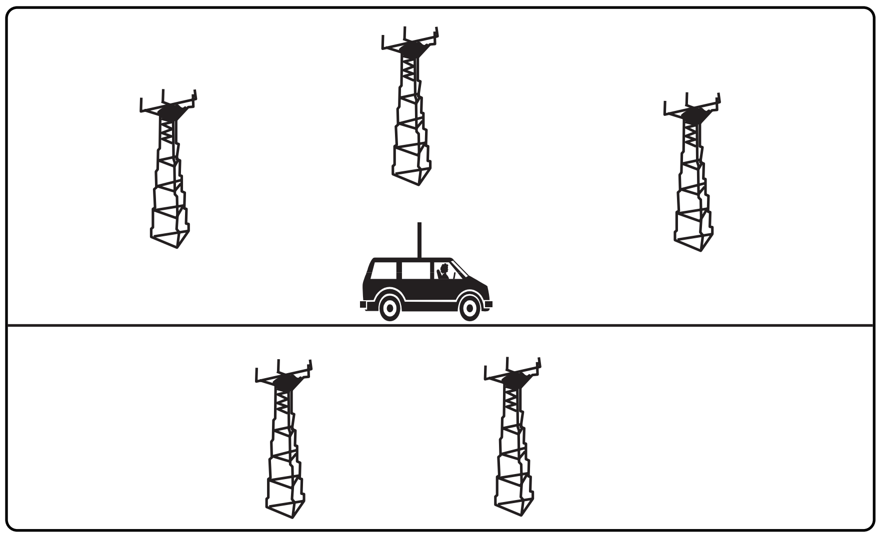


Figure 5. Typical drive-test van in a CDMA wireless network.

What is optimum network performance?

Service providers optimize the performance of their wireless networks to provide subscribers with the best possible service. Drive-testing is used to quantify this network performance. What is considered good performance? Since performance metrics vary from one service provider to another, no actual numbers will be given here. However, the types of measurements used to assess their networks are generally quite similar.

For example, phone-based measurements are used to measure: blocked calls, dropped calls, and forward link FER (frame erasure rate). Each provider determines their own limits to assure optimum network performance over the air interface.

Possible causes of network problems

There are a number of causes for blocked calls (failed originations), dropped calls, and poor FER.(A more detailed explanation is provided later in this document). These causes can include the following: poor RF coverage, pilot pollution, missing neighbors, search window setting problems, and timing errors. (Note: this document focuses on causes related to RF parameters rather than those associated with cell site capacity, backhaul capacity, or call processing software issues.)

Lack of RF coverage is often the cause of dropped calls and blocked calls. This may occur due to a localized coverage hole (such as a low spot in the road), or it could be due to poor coverage at the extreme edge of the coverage area. Pilot pollution is the presence of too many CDMA pilot signals. The additional pilots act like interference to the subscriber’s call. The missing neighbor condition occurs when a high-level pilot signal is received by the phone, and it does not appear in the phone’s neighbor list. Again, it acts as an interfering signal and can cause dropped calls and high FER. Likewise, dropped calls can occur when the search window is not set properly. In this case, the phone cannot find pilots that are in its neighbor list. Finally, base station timing errors can lead to dropped calls, since CDMA systems depend on having synchronous timing between base stations.

E7473A quickly identifies causes of network problems

We will show you how the integrated phone-and-receiver-based E7473A CDMA drive-test system can quickly find the causes of the network problems just described. One of the most powerful features of the collection system software is its ability to alert the operator when a problem occurs. Numerous predefined alarms are available to automatically detect the most common network problems. In addition, custom alarms—including those requiring Boolean conditions—can also be configured. Alarms can be easily selected from a list of predefined alarms such as the partial list shown in figure 6.

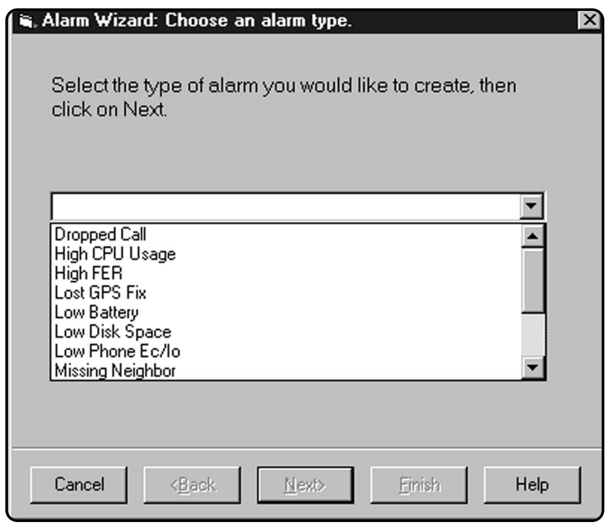


Figure 6. Alarms can be easily selected from a predefined list or configured for custom requirements.

An example of a missing neighbor alarm is shown in figure 7. It alerts the operator to the missing neighbor condition immediately, and provides the PN offset of the missing neighbor pilot. Terminology such as missing neighbors, pilot pollution, and timing errors will be explained more in Sections 4 through 8.

In addition to viewing the alarms during the drive-test, the alarms and the corresponding measurement displays can be replayed later by using the Playback feature shown in figure 8. The measurements are time-stamped for easy retrieval. Moreover, the alarms are conveniently indexed to fast-forward to the next alarm event using the familiar VCR-like control panel.

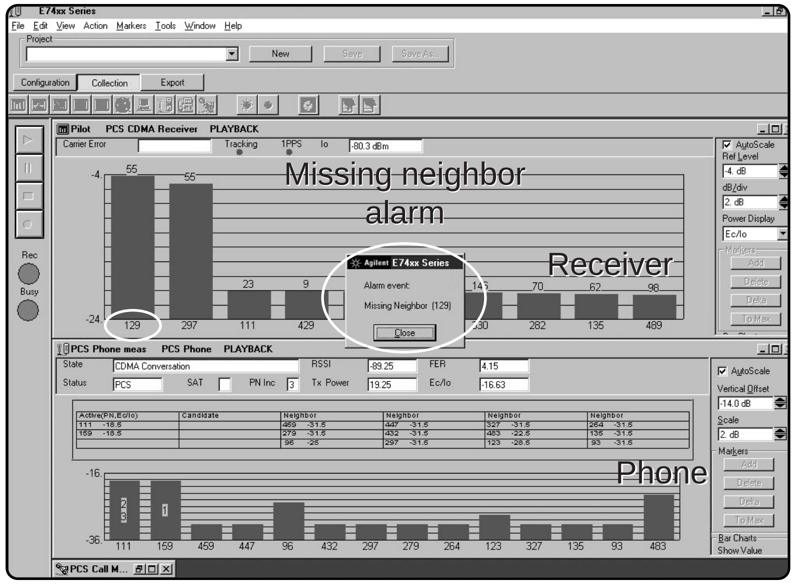


Figure 7. Missing neighbor alarm alerts the operator that the base station with pilot PN 129 is not in the phone's neighbor list.

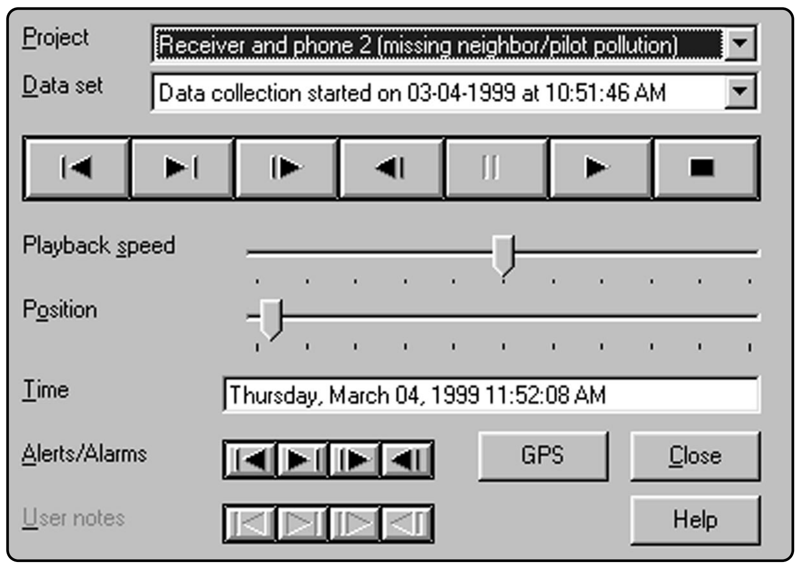


Figure 8. Playback feature in the E7473A software uses simple VCR-like controls to replay data collected during a drive-test. Alarms are indexed for fast retrieval.

Section 3: CDMA concepts; understanding drive-test measurements

CDMA background

A background tutorial on CDMA concepts will facilitate a better understanding of future measurement descriptions. If you are already familiar with the concepts of CDMA, please skip to page 12 for the phone-based measurement section or page 18 for the receiver-based measurement section.

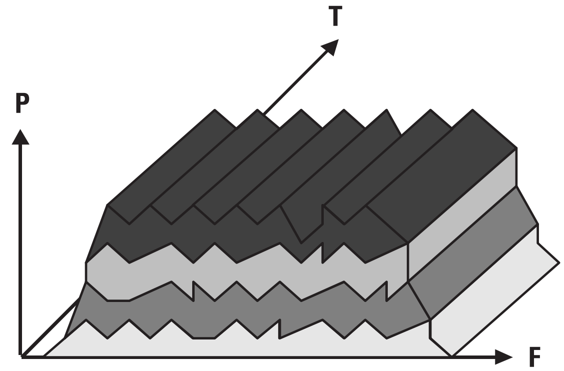


Figure 9. CDMA spectrum occupies 1.25-MHz bandwidth and consists of multiple code-domain channels, rather than individual narrowband frequency channels that were used in analog FM systems.

Cellular and PCS networks employing the CDMA air-interface are based on the IS-95 and J-Std008 standards, respectively. Rather than dividing the voice calls into frequency channels, as was done in analog FM networks, CDMA (code division multiple access) is a spread-spectrum format that utilizes orthogonally coded signals occupying the same 1.25-MHz spectral bandwidth. Refer to figure 9.

Each channel in a CDMA signal is spread by one of 64 orthogonal codes called Walsh codes, as shown in figure 10. The Walsh codes spread the signal over a bandwidth range of approximately 1.25 MHz. Most of the Walsh codes are used for voice traffic channels. The other codes are dedicated to pilot, paging, and sync channels. The paging channels (Walsh codes 1 through 7) are used by the base station to alert the phone. In most networks, only Walsh code 1 is used for paging, making codes 2 through 7 available for traffic use. The sync channel (Walsh code 32) is used to provide timing to the phone.

To understand how the pilot signal works, it is necessary to understand short codes. The last step in generating the CDMA signal in the base station is modulation of the data by a pseudo-random sequence called a short code. The short code is identical for all base stations, with one exception. Each base station has a different phase-delayed version of the same short code. This is usually represented as a time shift measured in chips. (A chip is approximately 0.8 microseconds.) This time offset in the short code is what uniquely identifies each base station. The time offset essentially acts as a color code.

The pilot channel (Walsh code 0) is an unmodified version of the short code just described. Therefore, it is identical for every base station, with the exception of the timing of its short code generator. It is this pilot channel timing offset that is used by a mobile phone to identify a particular base station, distinguish it from the others, and thereby communicate with the proper base station.

The pilot channel timing offset is expressed as a “PN offset” referenced to absolute time. The short code sequence repeats every 2 seconds, which is the period of the GPS even-second clock. Therefore, PN 0 aligns with the beginning of the short code period, exactly on the GPS even-second clock. PN 1 is advanced in timing by 64 chips. PN 2 is 128 chips higher than PN 0, and so on. “PN” stands for “pseudo noise,” a term that has its origins in spread spectrum theory. There are up to 512 unique PN offsets available to network operators, although only a subset is typically used. The set of PNs is further confined to integer multiples of a PN value known as the PN increment. Common PN increments used by wireless service providers are 3, 4, or 6. A PN increment of 3 means that PN 0, PN 3, PN 6, PN 9, for example, may be assigned to base stations or base station sectors in the network. Each CDMA operator selects a value of PN increment based primarily on its base station density. A PN increment of 3 provides more PN offsets than a PN increment of 6, since the total number is computed by dividing 512 by the PN increment. PN values may be reused in the same network, provided the base stations are located at a significant distance from one another and their antennas are pointed away from each other.

It is the pilot channel that is measured by the digital receiver-based drive-test system. To identify a base station, the receiver measures the timing offset of the short code comprising the pilot channel. The receiver obtains its precise timing from the pulse-per-second reference signal available on standard GPS receivers. Numerous examples of base station pilot displays will be shown later when the drive-test measurements are described. (Note that other test equipment from Agilent Technologies is available to analyze all the Walsh codes. This equipment can be carried to a base station and connected directly to the RF output to display code domain power. This is a separate application, referred to as cell site maintenance, and will not be covered in this product note. Refer to the 8935A CDMA base station tester for more information.)

Measuring pilot signals

Drive-test systems exploit the fact that the pilot channel (Walsh code 0) transmits continuously and provides a means of identifying each base station. Scanning the pilots allows engineers to quickly examine the RF coverage in the wireless network. Figure 11 is a display of the levels of the strongest pilots measured by a network-independent Agilent digital receiver. Note the PN offsets at the bottom of each of the bar graphs, identifying the base station or base station sector that transmitted each pilot. The numbers shown at the top of the bars represent the Ec/Io of each pilot signal. This is a measure of the relative amplitude of each base station received by the drive-test system, as described in the next section.

Figure 12 is a depiction of the four closest base stations that correspond to the four pilot signals shown in figure 11.

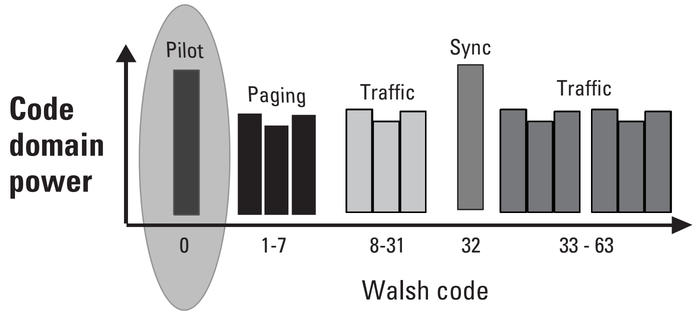


Figure 10. Walsh codes comprising CDMA signal.

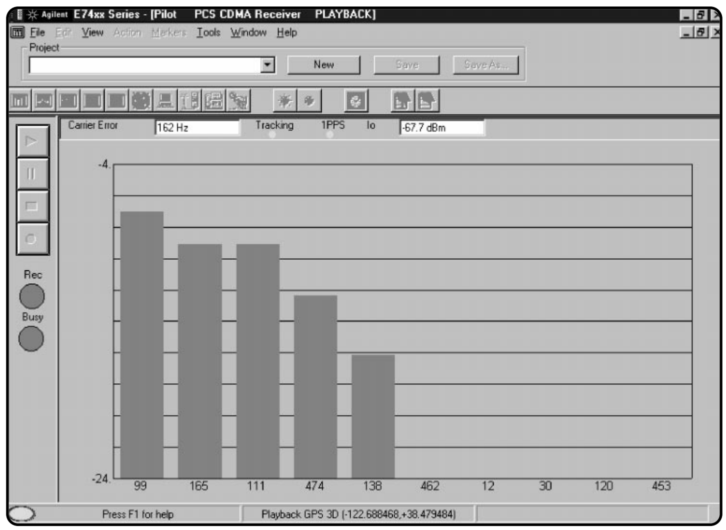


Figure 11. Receiver-based drive-test measurement display of the four highest-level pilots.

The diagram is simplified for illustration purposes and does not include the sectorization normally present at each base station. Note also that it is not always the closest base station that produces the highest received pilot signal strength.

Different propagation conditions often exist that allow distant signals to be received at higher levels, presenting difficult-to-solve problems. It will be shown later that the Agilent receiver-based drive-test tool helps diagnose these problems.

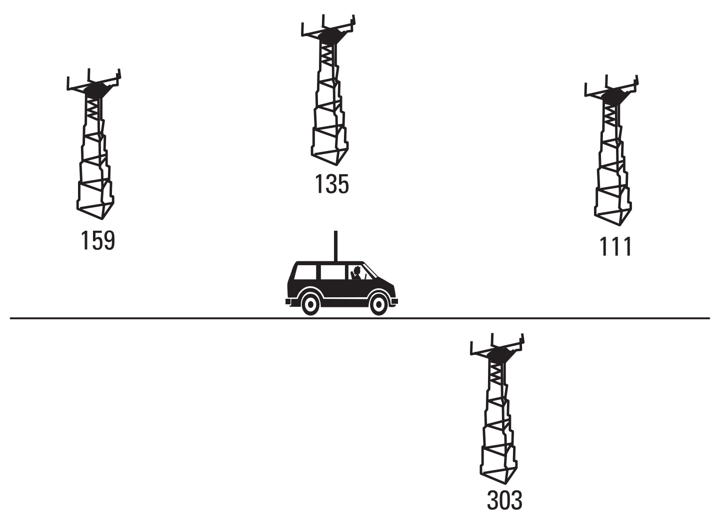


Figure 12. Wireless network consisting of multiple base stations.

Ec and Io definitions

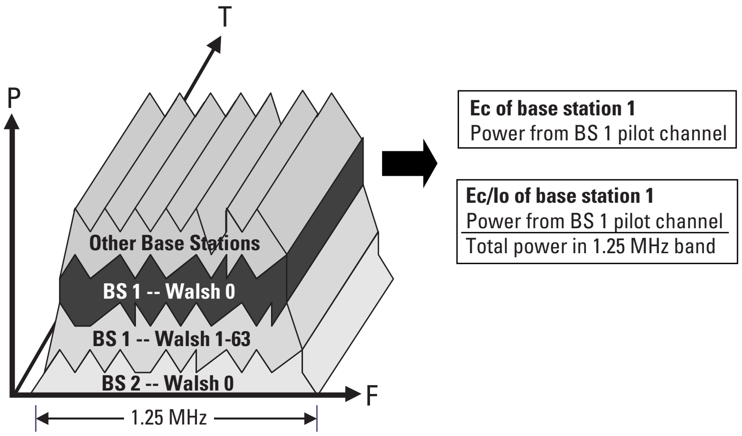


Figure 13. CDMA composite signal consisting of all the Walsh codes of each base station.

Depending on whether a phone or a receiver is used to perform the pilot scanning, the pilot displays are usually measured in units of Ec, Io, or Ec/Io. Ec is the signal strength measurement of the pilot expressed in dBm units. For example, the pilot signal may have an Ec value of –50 dBm or –80 dBm or –100 dBm, depending on where the drive-test equipment is located with respect to the base station transmitting that pilot signal. Figure 13 illustrates that each base station Ec is just a small portion of the total power in the 1.25 MHz bandwidth channel.

Io is a measure of the total power (dBm) within the 1.25 MHz bandwidth channel. It includes the power of all 64 Walsh codes from each base station and any noise or interference that may reside in the 1.25 MHz channel. Practically speaking, Ec/Io is the power in an individual base station pilot divided by the total power in the 1.25 MHz channel, expressed in dB. It provides a useful ratio to compare the power levels of the base stations with respect to one another. (The more technical definition of Ec/Io is the ratio of energy per chip to the interference power spectral density. It is equivalent to thinking of these terms—Ec and Io—as the ratio of powers.)

Pilot signals can be displayed by drive-test solutions in several ways, depending on whether the measurements are performed by a network-independent receiver or a test mobile phone. The previous pilot displays originated from a receiver. The receiver measures all the pilots, completely independent of any network instructions. In contrast, a phone-based drive-test measurement display will look somewhat different.

To better understand the contributions that the phone and receiver each provide, the next two sections of this document are split between phone-based and receiver-based drive-test measurements. The remainder of the document describes the benefits of combining the phone and receiver into an integrated drive-test solution.

Cell breathing

Cell breathing is a term used in CDMA to describe how the coverage of a cell site can change as traffic loading changes. This is important to understand, because drive-testing at midnight will produce different results than drive-testing at rush hour. The usable coverage of a cell site is reduced as more subscribers use the network—such as during the day at rush hour.

Note that the power control in cdmaOne applies to the traffic channels and NOT the pilot channel. If a certain traffic channel (in other words, Walsh code) of the base station requires more power transmitted to a distant mobile, the power is changed in that channel only and NOT in the pilot channel (nor in the paging and sync channels).

Let's take two examples:

The first example shows how the location of the subscriber phones with respect to the base station, will affect the RF coverage. Suppose that there are five subscribers near the base station, consequently, the power control on the traffic channels is set to transmit a fairly low power. Therefore, the Io is quite low, which means that Ec/Io can be quite high (for example, –8 dB). Remember that Ec is measured on a pilot, which does not change its power (in contrast to the traffic channels, which do), and that Io is comprised of all other pilots in the frequency channel and all the traffic channels (Walsh codes) of the base stations being received. Now, if those same five subscribers are at the fringe of the coverage area, the power control in the traffic channels will cause the base station to transmit more power, causing Io to increase, and reducing Ec/Io (for example, –15 dB).

In summary, RF coverage of the pilot channel does not change as the power is adjusted using power control in the traffic channels. However, increased power in the traffic channels causes overall Io to increase, thereby decreasing Ec/Io. The end result is that the overall coverage area is decreased due to the increased Io, which acts like interference to the phone.
The second example shows how RF coverage can be affected by the time of day. Suppose that there are five subscribers being served by a base station at midnight. Ec/Io is high, (for example, –8 dB). At rush hour, the number of subscribers increases to 30. The Ec/Io is lower for this condition because the Io goes up as more traffic channels are in use. Therefore, the cell coverage area is reduced during rush hour.

Locations of the phone subscribers and the total number of subscribers impact the power control function of the phone and base station. However, this power control applies to the traffic channels, and not the pilot channel (or sync or paging). The result is that RF coverage is constantly changing. To maintain an optimized network requires an ongoing process of drive-testing under various loading conditions.

Section 4: Phone-based drive-test measurements

CDMA phone concepts

Since a test mobile phone is dependent on the network, it displays the pilots that it is instructed to measure. To better understand how a phone measures base station pilot signals, refer to figure 14. A phone categorizes base station pilots into three major sets: active, candidate, and neighbor. All other pilots are part of a fourth group called the remainder set. As described later, the Agilent receiver-based drive-test tool measures all pilots, including those in the remainder set, which are often the source of interference.

As figure 14 illustrates, the phone is constantly in communication with many base stations. Active pilots represent those base stations that are currently involved in transmitting and receiving a “live” call. Candidate pilots indicate those base stations that are transitioning into or out of the active set, depending on whether their power levels rise above or fall below a network-defined threshold (Tadd or Tdrop). The neighbor pilot set includes a list of base stations that are potential choices for the active set. The wireless service provider’s network planning staff programs the network to download the neighbor list to the mobile phone. It usually epresents the nearby base stations that are servicing the mobile phone. Consequently, the neighbor list is constantly changing as the mobile moves through the network coverage area. Each base station sector has a unique neighbor list. When a call is in the hand-off process from one cell to another (or one sector to another on the same cell), the phone’s neighbor list is comprised of the neighbors associated with each sector involved in the hand-off.

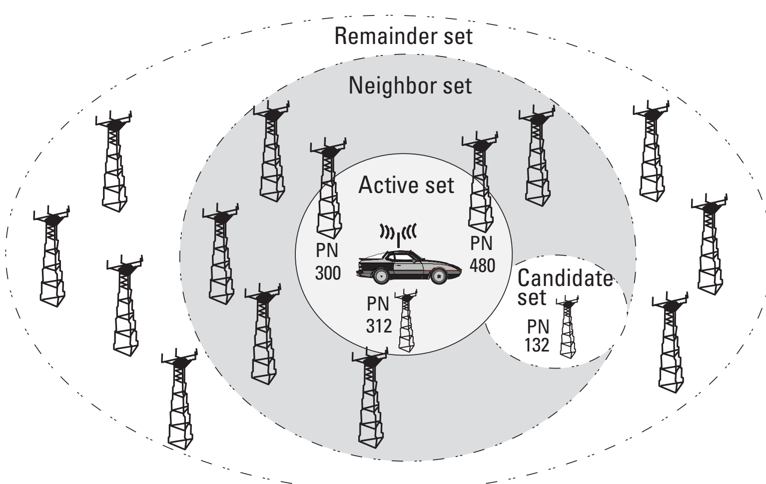


Figure 14. Active, candidate, and neighbor pilot set lists are constantly being updated.

To represent the three pilot sets, the E7473A software displays the pilot categories in colorred for active, yellow for candidate, and blue for neighbor. Since this product note does not use color, the categories are indicated by the accompanying text descriptors above each pilot set in figure 15.

Most drive-test tools use either a test mobile phone or a standard off-the-shelf subscriber phone, a laptop computer, and a GPS receiver and antenna. For example, the E7473A phone-based system uses a commercially available CDMA subscriber phone, as shown in figure 16. (Refer to the E7473A configuration guide to ensure that the correct options are ordered. The literature number is given at the end of this document.)

While describing the functions available with the E7473A phone-based solution, it is important to know that phone-based tools are a minimum requirement for drive-testing. Basic measurements of dropped calls and blocked calls (also called access failures) are needed to understand the network performance from the subscriber's perspective. The phone-based solution provides a wide variety of measurements, including dropped and blocked call statistics, pilot displays, FER, and messaging.

Let's review the three main phone functions: phone measurement displays, phone messaging displays, and phone call control displays.

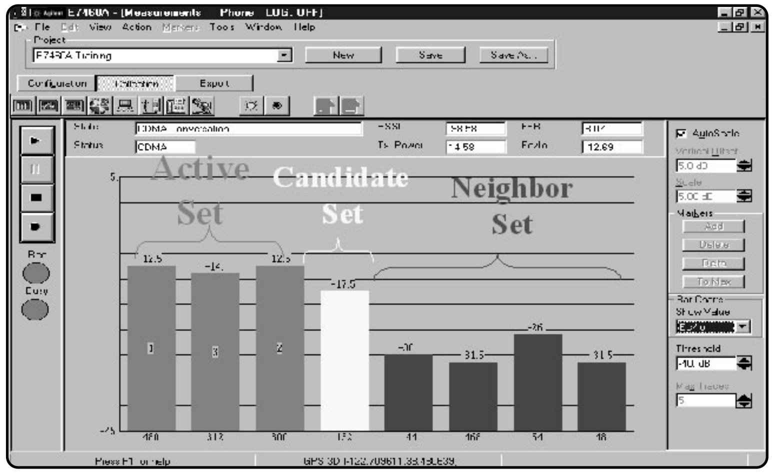


Figure 15. Phone-based drive-test measurement software shows active, candidate, and neighbor pilots.

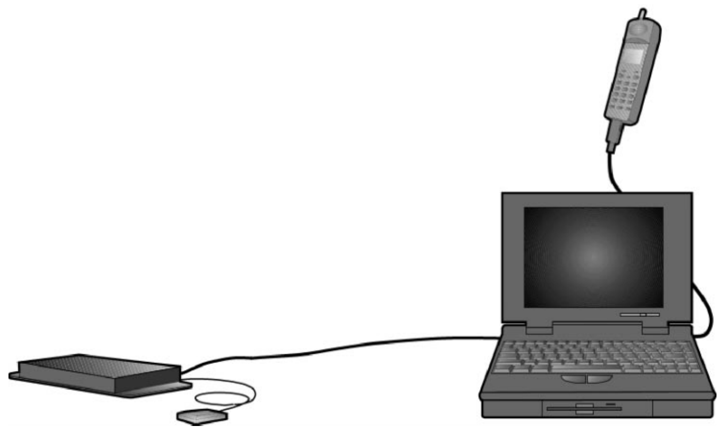


Figure 16. E7473A phone-based drive-test tool with optional laptop PC, optional GPS receiver and antenna, and customer-supplied CDMA phone.

Phone-based measurements

While it is possible to display all the phone measurement windows on the same display, for clarity purpose, each one will be viewed and described separately.

Phone pilot and PN list displays

Figure 17 shows one of the phone-based measurement displays. Active, candidate, and neighbor pilot power measurements are shown. The number inside the active pilot indicates which rake receiver fingers of the phone are currently demodulating the active phone call. In this example, only rake receiver finger #1 is being used. (Figure 19 shows a call in three-way hand-off.) The bottom half of the display in figure 17 is the "PN list" feature that categorizes the pilots into active, candidate, and neighbor pilot sets. The graphical and tabular displays of pilot data provide two easy ways to analyze coverage and neighbor list conditions.

In addition to the phone pilot display measurement, several other measurements can be made using the E7473A phone-based system. These measurements can be selected from the measurement menu shown in figure 18.

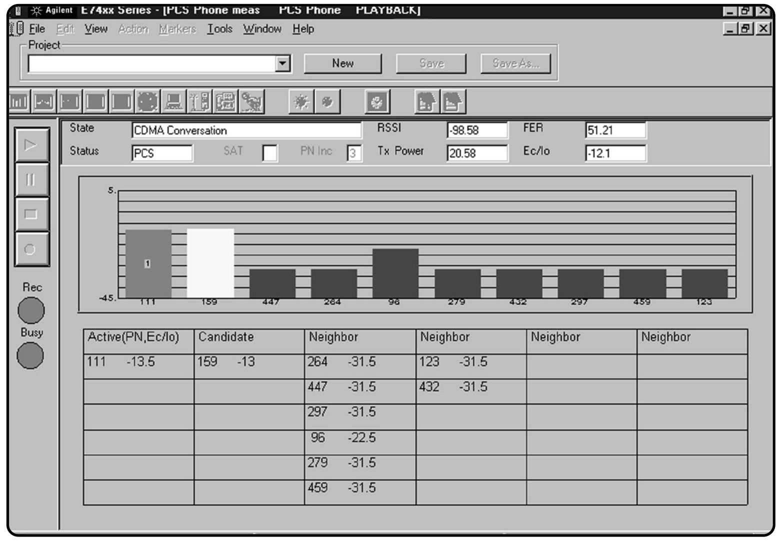


Figure 17. Phone pilot display (top) shows active, candidate, and neighbor pilots. PN list display (bottom) categorizes pilots for easy analysis.

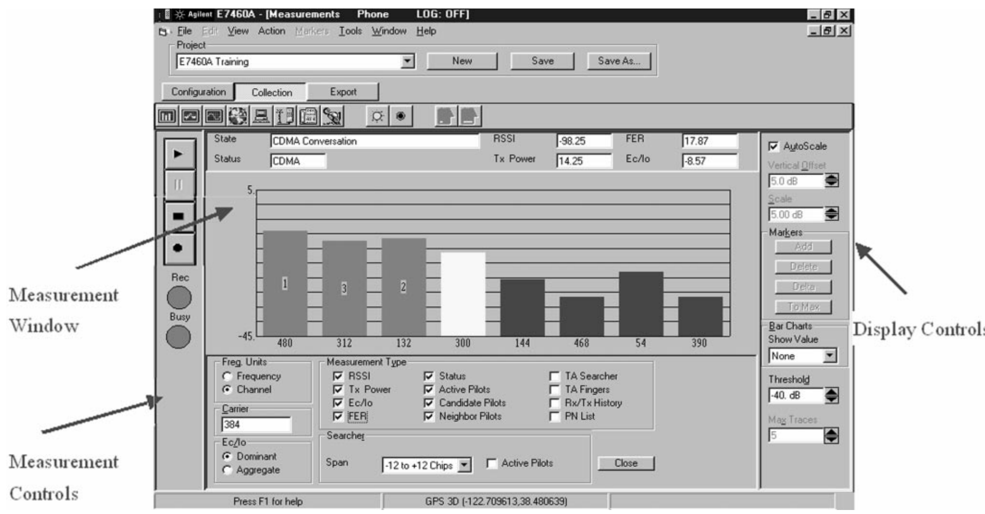


Figure 18. Phone measurement setup menu.

Phone rake finger display

Figure 19 shows the active pilot measurement display on the top half and the rake receiver TA finger display on the bottom half of the window. This example illustrates a call in three-way soft hand-off among three base stations-PN 135, 303, and 159. Soft hand-off describes a condition where two or three base stations simultaneously serve the same subscriber call to allow a smooth hand-off without any annoying clicks or interruptions like those found in many analog systems. Soft hand-off is beneficial to subscribers because the likelihood of being dropped is decreased. However, as the number of calls in soft hand-off increases, the overall call capacity of the network decreases.

Another related condition is softer hand-off which occurs when two or more sectors of the same base station are simultaneously holding a call with the same phone. To tell whether the phone is in soft hand-off or softer hand-off requires knowledge of which PN offsets are associated with the sectors of the same base station.

Finally, occasionally CDMA calls can be handed off from a base station at one carrier frequency to another base station at another carrier frequency (in other words, in a different 1.25 MHz channel). This condition is called hard hand-off and only occurs in networks with multiple carriers. (A hand-off from one switch to another while maintaining the same carrier is also often referred to as a hard hand-off.)

PN list display

Figure 20 shows the PN list measurement display that was briefly mentioned earlier. It separates the pilots into the active, candidate, and neighbor sets. The value of Ec/Io are shown for each pilot

TA searcher display

Figure 21 shows the TA searcher data in the lower window. The fourth finger of the phone's rake receiver is called a searcher. The searcher is used to search for pilots, including those in the active, candidate, and neighbor sets. The search window must be set properly by the wireless service provider. Setting it too wide causes needless speed degradation. Setting it too narrow opens the possibility of missing the pilot altogether. The TA (temporal analyzer) searcher display is a time-domain representation of the searcher activity, providing the optimization engineer with some insight into the multipath conditions. The Y axis is the amplitude level in dBm. The X axis is timing in chips. Markers can be placed on the traces to make measurements on the data. When viewed on a PC, the TA trace data is colorcoded to match the colors of the PN list entries shown in the top half of figure 21. (A more detailed explanation of optimizing search window settings is offered later, refer to page 23. The Agilent receiver-based drive-test tool provides another more extensive measurement capability that characterizes both absolute delay and multipath delay spread. This significantly improves the RF engineer's ability to correctly optimize phone search window settings.)

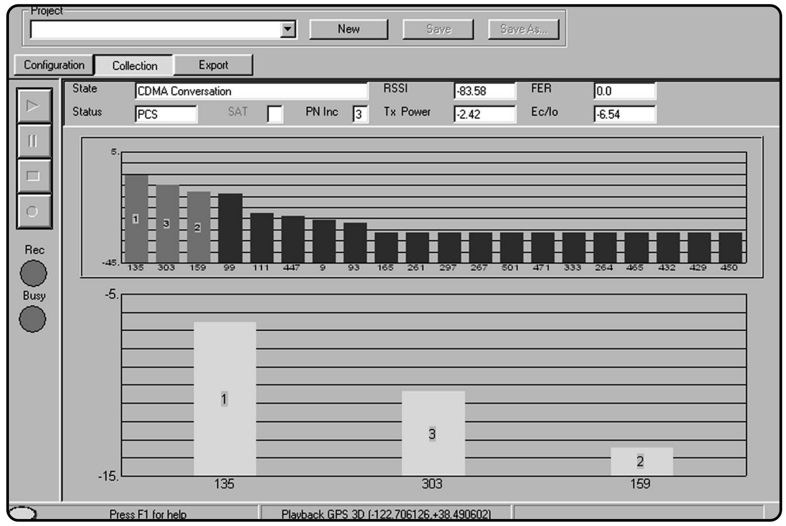


Figure 19. Phone measurement window showing rake receiver fingers.

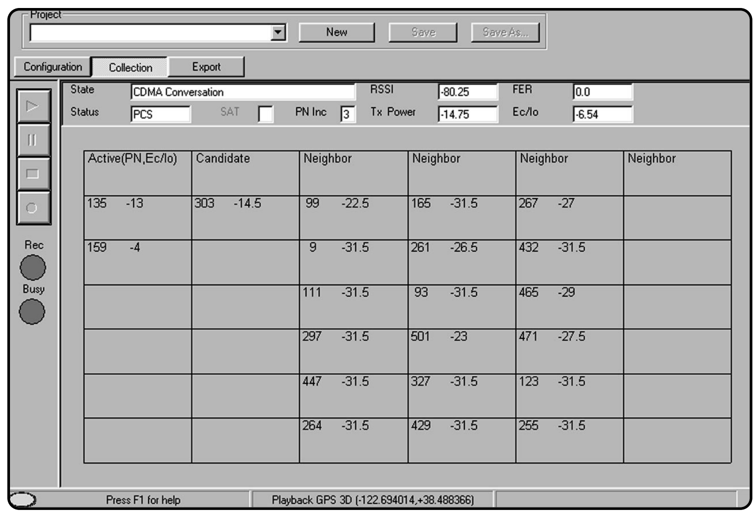


Figure 20. Phone measurement window showing PN list.

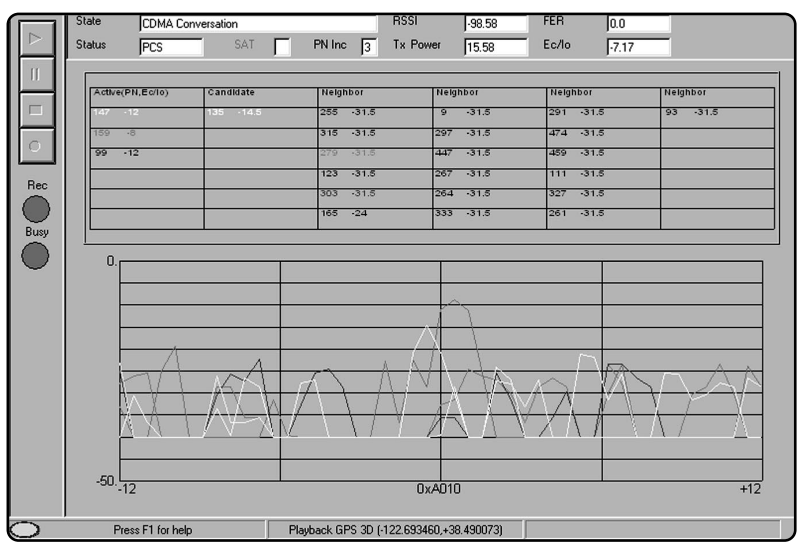


Figure 21. Phone measurement window showing TA searcher and PN list displays.

Rx/Tx history
The E7473A phone display in Figure 22 is a strip chart showing the transmitted and received power for the phone over a moving 2-second window. Received power is identical to the RSSI (received signal strength indicator) value shown at the top of the window. Transmitted power on the strip chart is equal to the transmit power indicator. The other parameters that are shown as instantaneous values at the top of the window include FER (frame erasure rate) for the current call and Ec/Io of the primary server (strongest active PN). An adjustable averaging window for FER is also available.

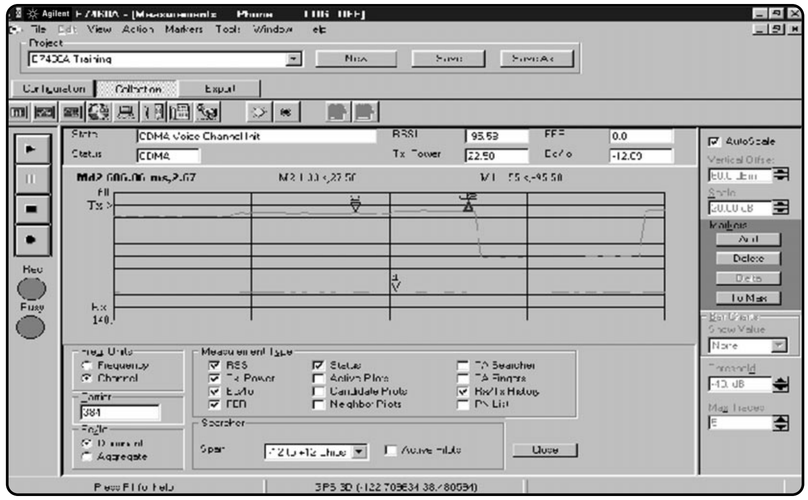


Figure 22. Phone measurement window shows transmitted/received power strip chart, and instantaneous values of transmitted and received power, FER, and Ec/Io of primary server.

Phone messaging display

Decoding the layer 3 messaging is another measurement performed by the phone. Figure 23 provides an example of the messaging screen, including an expanded view of the tree structure for one particular message. Message categories include access, paging, sync, reverse traffic, and forward traffic. Any subset of these can be selected, making it easier to locate specific messages.

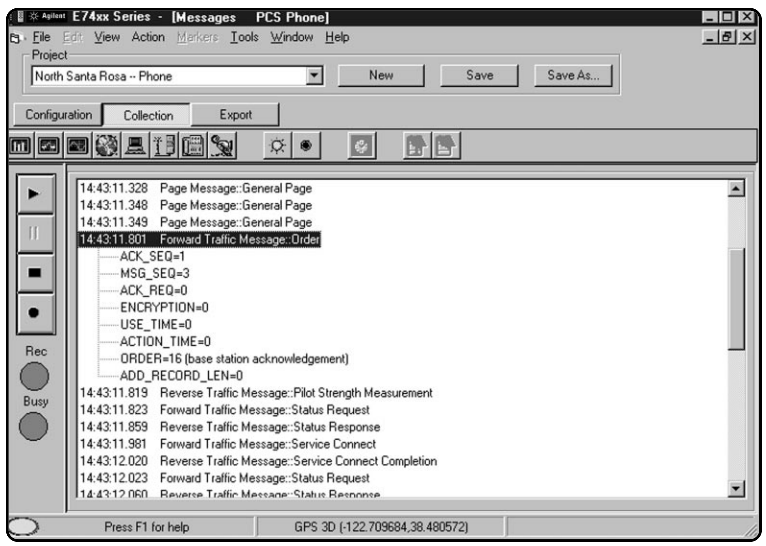


Figure 23. Phone measurement window showing messaging.

Phone call setup display

Finally, the software makes important measurements of blocked call and dropped call statistics. Figure 24 shows the phone setup window for automating the call process. The phone number is entered, the number of calls is input, and the other necessary parameters are set.

Phone-based drive-test system summary

Phone-based tools like the E7473A are necessary for assessing the performance of the wireless network with call statistics such as blocked and dropped calls and FER as a function of location. While phone-based tools tell the optimization engineer "what" the problem is, they do not disclose "why" the problem occurred. Why did dropped calls occur at specific locations? Why was FER so high in a particular sector? Because phone-based tools do not indicate the source of the problem, a companion receiver-based tool that is integrated with the phone into a single drive-test solution was developed.

Since phone-based tools are controlled by the network, they lack the independence to make measurements in an unconstrained manner. The phone's timing is initially derived from the network using the base station sync channel (Walsh code 32). Any timing errors in the base station will cause subsequent errors in the phone-based measurement tool. In addition, the network tells the phone which base stations to scan, based on the neighbor list that is downloaded to the phone over the air-interface. Base stations that are not included in the neighbor list may never be measured by the phone, although they can cause major interference, resulting in dropped calls. In contrast, the E645X receiver is completely independent of the network. It measures all the pilots detected at its RF input. It has the capability to measure all 512 pilots in approximately 1 second, although this number of pilots is not realized in a network. Refer to the following section for more information.

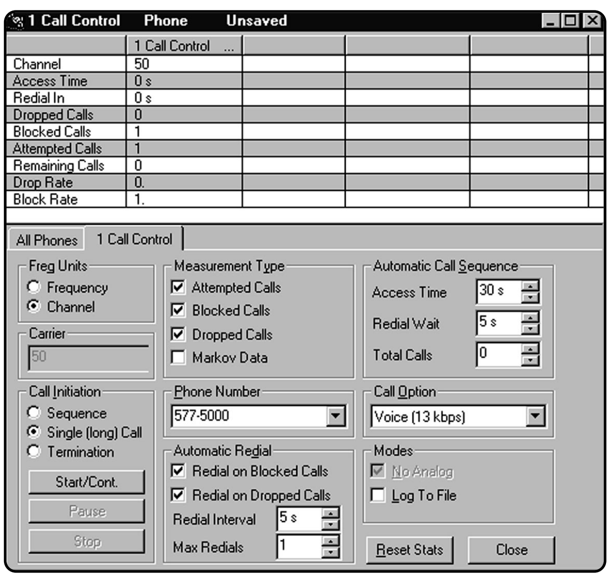


Figure 24. Phone call control window.

Section 5: Receiver-based drive-test measurements

Overview

This section reviews the concepts, measurements, and benefits of the E7473A CDMA receiver-based drive-test system. Section 4 described how a phone-based drive-test solution is required to tell “what” network symptoms exist, including dropped calls, access failures (blocked calls), or high FER (frame erasure rate). This section will illustrate that a receiver-based drive-test tool is necessary to tell “why” the problems are occurring.

Phone-only-based drive-test systems often have the same network problems they are trying to resolve. What is needed is a network-independent drive-test solution. The Agilent receiver-based drive tool was specifically designed to overcome this problem. Since the receiver uses GPS to synchronize its timing, it does not need to be tied to the network. Furthermore, it scans all 512 pilots, rather than being limited to the neighbor list as a phone is.

The compact, portable digital receiver is shown with a phone in the integrated E7473A drive-test system in figure 25. (Refer to the E7473A configuration guide to ensure that the correct options are ordered. The literature number is given at the end of this document.)

Before describing the receiver functions in detail, it is important to understand that having both a phone and a receiver integrated into the same system assures the highest network optimization. Figure 26 illustrates how the integrated Agilent drive-test system can help to determine the source of network air-interface problems. The phone can tell the “what” and the receiver can tell the “why.” For example, the phone-based software can measure the drop call percentage or FER percentage. In this example, the phone display indicates that FER is high at 13 percent. This can cause subscribers to experience dropped calls or poor voice quality, but it does not reveal why this condition is happening. The receiver can measure all the pilots, and indicates that PN 428 is a rogue pilot that is not in the phone’s neighbor list. Therefore, this missing neighbor can cause excessive interference to the phone, with high drop rates and high FER. In this case, the missing neighbor is the dominant pilot, so the problem is even worse. Optimization engineers using only phone-based tools could spend hours and perhaps days trying to resolve this problem. Using the integrated E7473A receiver and phone solution with its automatic software alarm capability, engineers can significantly reduce the time and resources spent resolving problems of this nature.

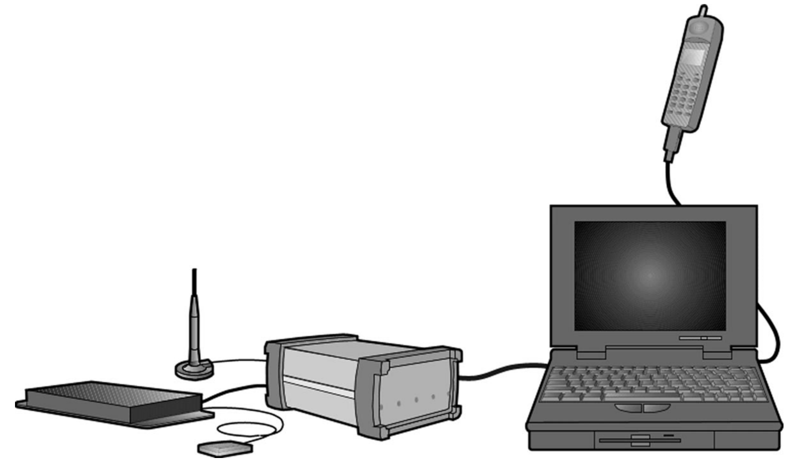


Figure 25. E7473A integrated drive-test system based on the E645X network-independent digital RF receiver and phone-based tools. An optional external GPS receiver is also shown.

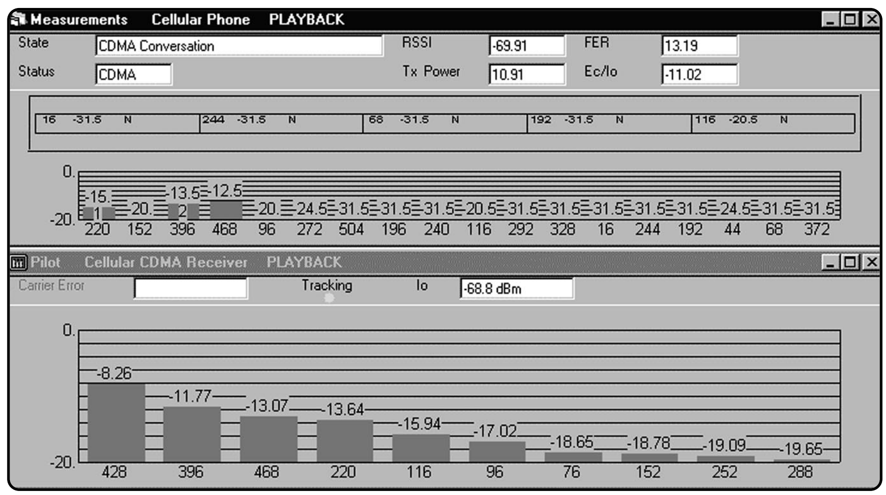


Figure 26. Integrated E7473A drive-test solution with RF receiver and phone quickly identifies “missing neighbor” condition.

Additional case study examples illustrating the benefits of the integrated phone and receiver will be presented later.

In contrast to a mobile subscriber phone or a phone-based drive-test tool, the E645X receiver does not use the sync channel of the base station for its timing. Rather, it uses GPS (global positioning system) satellites to obtain the one pulse-per-second required to accurately measure all the pilots that are detected at the E645X RF input. GPS is also used to tag the location (longitude and latitude) to each measurement made by the receiver. An optional built-in GPS receiver that resides in the E645X receiver provides the most compact and portable solution. See Figure 27.

If an external GPS receiver is desired or already available, it connects to the E645X receiver via an RS-232 connection. Figure 28 shows an external GPS receiver connected to the E645X RF receiver. Options for differential GPS (for more accurate location) and dead reckoning GPS (for providing GPS location and one pulse-per-second when driving in tunnels or other areas obscured from line-of-sight with GPS satellites) are available on the E7473A drive-test systems.

In preparation for a series of wireless network optimization case studies that illustrate how the E7473A integrated receiver and phone based solutions solve problems, some background information requires review. This section's focus is on the E7473A receiver-based solution. Understanding the basic concepts of how a receiver is used in drive-test measurements will also be covered. Three subsections correspond to the three virtual front-panel icons in the Agilent receiver-based software: pilot scanning measurements, CW and channel power measurements, and spectrum measurements.

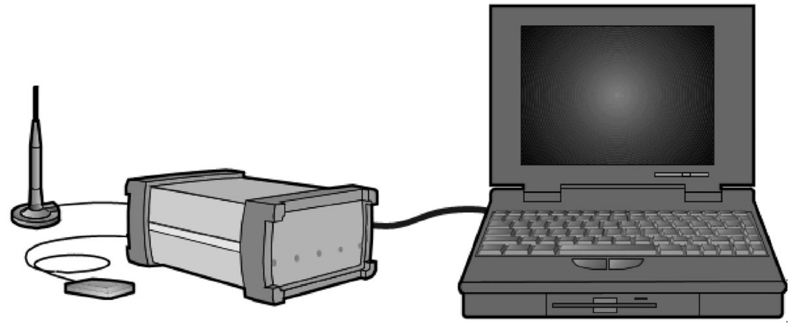


Figure 27. E7473A drive-test solution with E645X RF receiver, optional internal GPS receiver and GPS antenna, optional RF antenna, and optional laptop PC.

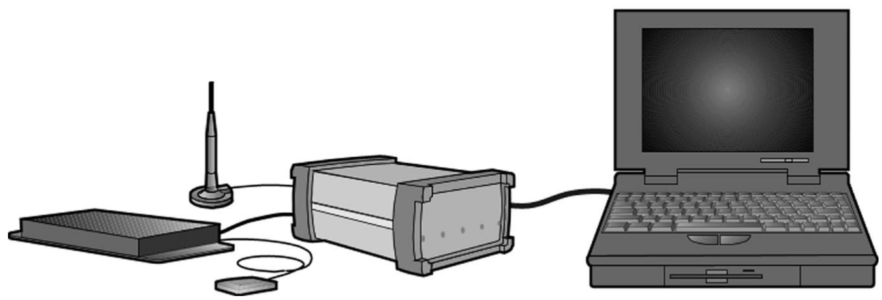


Figure 28. E7473A receiver-based drive-test system with optional external GPS receiver and GPS antenna, optional RF antenna, and optional laptop PC. External differential GPS receiver and external dead reckoning GPS receiver are also available as options.

CDMA pilot scanning overview

Figure 29 shows a display of one of the measurement windows taken from the E7473A receiver-based system. The bar chart is a *Top N* display of the strongest pilots measured by the E645X receiver and placed in descending order of power level. The value of N can be set between 1 and 20. The PN offset values of the pilots are shown at the bottom of each bar. The y-axis choices are either Ec or Ec/Io. There are many choices available for the value that is displayed on top of each bar. The choices include delay, Ec, Ec/Io, aggregate Ec, aggregate Ec/Io, delay spread, amd aggregrate-peak. In this example, the value displayed is Ec/Io. To change what is displayed on the top of each bar, simply select the desired measurement parameter in the *Show Value* entry window, as seen in the lower right-hand corner of the display. The Top N display shown here is more than an Ec/Io pilot scanner. The Top N display is one of the most versatile and useful measurement displays for network optimization, since several measurements are made simultaneously on the same data set.

Alternatively, the *All Pilots* display can be selected as shown on the top half of Figure 30. It is an amplitude versus PN offset display of all the pilots detected by the receiver. It is capable of measuring and displaying up to 512 pilots in approximately 1 second. The Top N display is also shown to illustrate that both views can be displayed simultaneously. The Top N display simply allows the detected pilots to be arranged in ascending or descending order. Likewise, the bars can be sorted by X value, Y value, history, or *Show Value*.

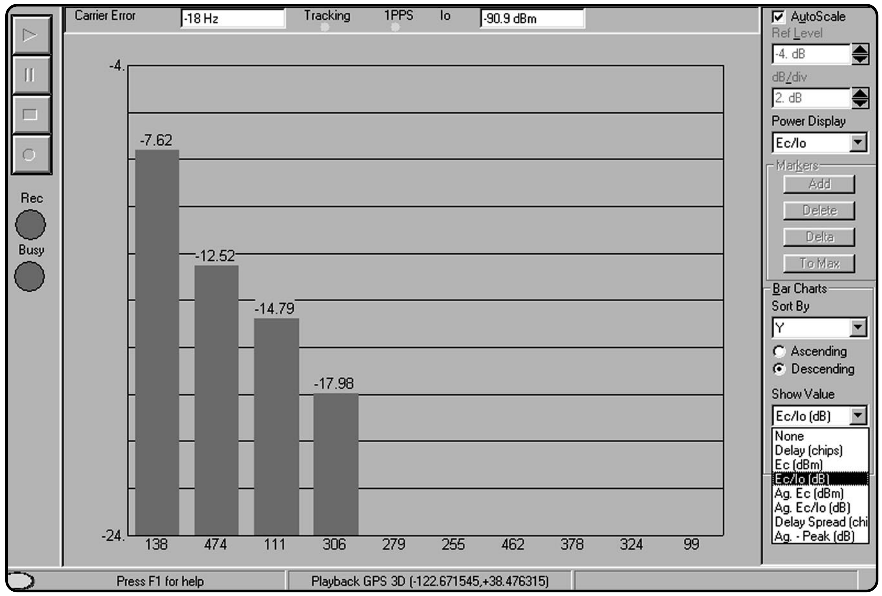


Figure 29. Receiver Top N pilot measurement window.

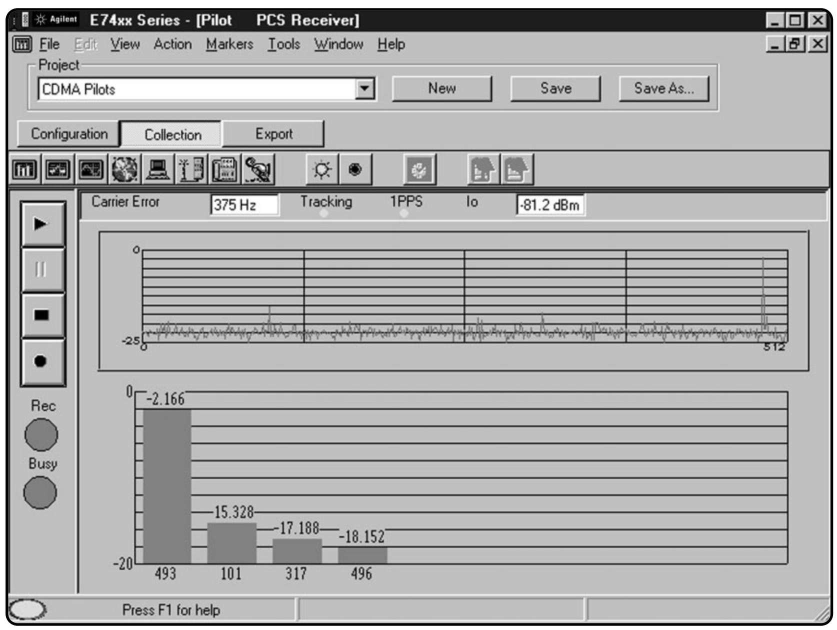


Figure 30. Receiver All Pilots measurement window (top) and Top N window (bottom).

It is important to remember that the receiver derives its timing from the GPS one pulse-per-second signal. The receiver's timing is aligned with the even-second clock of GPS, which is the same timing signal that CDMA base stations use. To correctly measure the pilots, the receiver requires knowledge of the PN increment for the particular network. The PN increment is the spacing of the pilot signals within a given service provider's network. A PN increment of 3 means that PN 0, PN 3, PN 6, PN 9, can be used by a provider. The measurement setup window for the receiver is the user interface for entering this PN increment value, as seen in figure 31. In addition, the frequency of the CDMA carrier (or its channel number) is entered using this setup screen. (To simplify the entry of the PN increment and channel frequency, E7473A systems with the integrated phone and receiver include a link feature that automatically places the values into the receiver setup screen when the phone acquires its settings.)

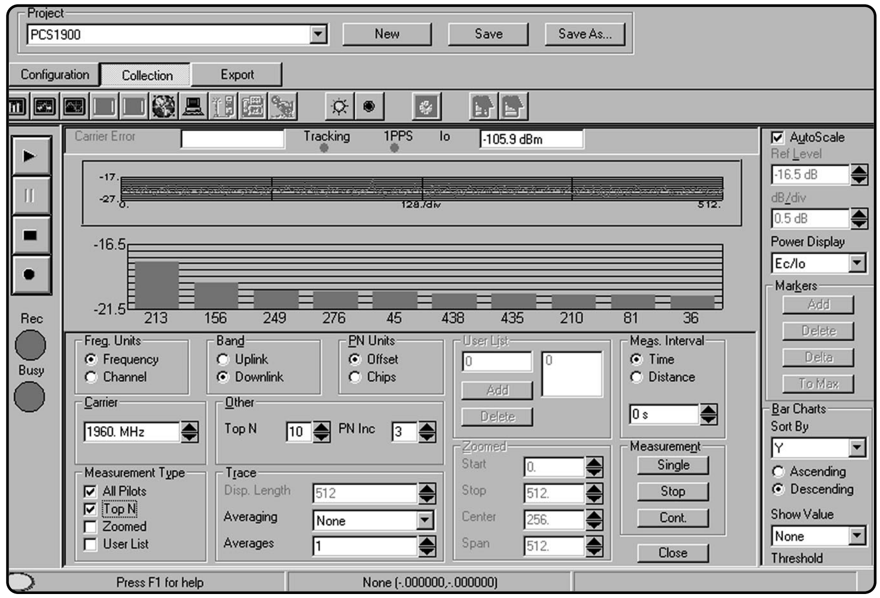


Figure 31. Receiver measurement setup window showing PN increment of 1.

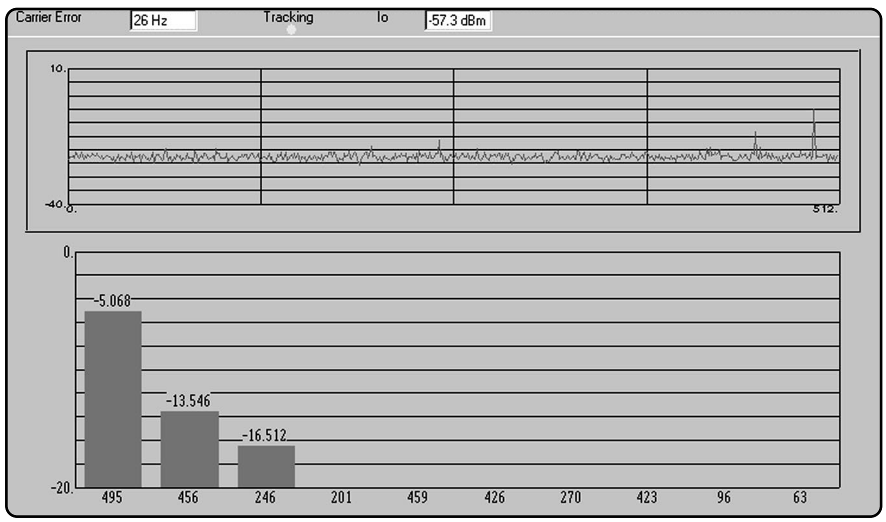


Figure 32. Properly optimized network. Receiver display indicates that pilot pollution is not present. Both the All Pilots and Top N displays are shown.

The other measurements provided by the pilot menu include *User List* and *Zoomed pilots*. User list is used to display only those PNs that are of interest. The *Zoomed pilots* display is useful for closely examining the amplitude versus time response of a particular pilot to qualitatively characterize the multipath conditions. This feature is often used in conjunction with the delay, delay spread, and aggregate - peak information available from the *Top N* and *User List* measurements.

The receiver virtual front panel displays provide useful background information for some of the measurement applications described in this section and again later in the case studies. When combined with the GPS location information, the Top N display measures general RF coverage of each pilot and evaluates interference. As seen earlier in the missing neighbor measurement scenario, the pilots detected by the receiver are compared to those measured by the phone-based drive-test tool. The pilots that are missing from the phone neighbor list act like interference to the phone and result in dropped calls or poor FER

Pilot pollution measurements

Another form of interference in CDMA networks is pilot pollution. It is defined as the presence of more than three pilots having significant power. The rake receiver of the phone has three fingers that are used either to demodulate up to three different pilots in a soft hand-off situation, or to demodulate up to three multipath components of the same pilot, while maintaining a call in low signal-level conditions. (A combination of the soft hand-off and multipath conditions can also occur.) If more than three significant pilots are presented to the rake receiver at one time, it cannot make use of them. In fact, the presence of a high-level fourth or fifth pilot results in excessive active set churn, higher levels of Io, and consequently worse Ec/Io. The result of all of these conditions is often higher FER or a potential increased dropped-call rate.

Figures 32 and 33 show examples of both a good network (with only three significant pilots) and a bad network (having seven or eight high-level pilots). This pilot pollution condition is easily measured by the receiver-based drive system, since it can measure all the pilots independently of network neighbor lists. Phone-based tools are capable of measuring multiple pilots, but there is no guarantee that all pilots will be detected, due to neighbor list limitations. Pilot pollution and missing neighbor conditions are often closely related. Having an integrated receiver and phone in combination with automatic software alarms ensures the best detection of these problems in the minimum amount of time. This keeps operating costs to a minimum, compared to phone-only drive-test solutions, that often require multiple drives and higher labor costs.

The upper halves of the displays in Figures 32 and 33 show the *All Pilots* measurement. The X axis ranges from PN 0 to PN 512. The lower half of each display is the *Top N* measurement, showing the pilots in descending order of Ec/Io value.

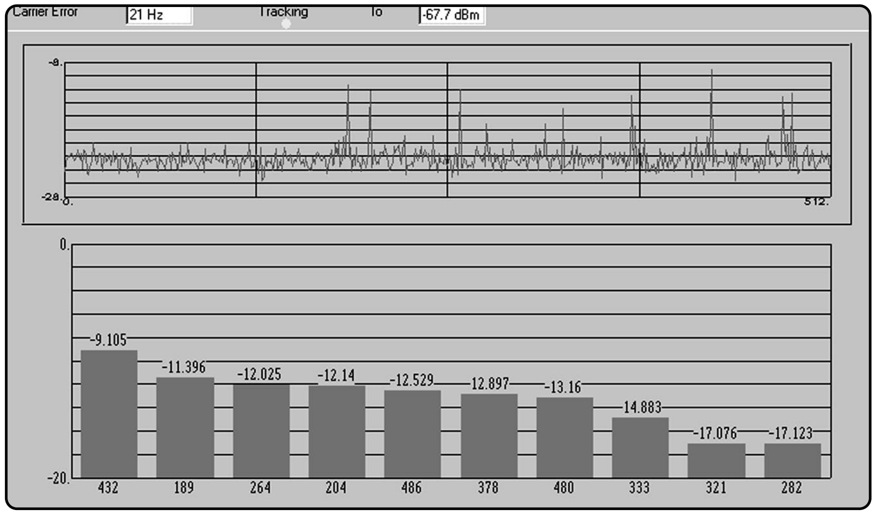


Figure 33. Poorly optimized network. Receiver display indicates that pilot pollution is present, since more than three significant pilots are present.

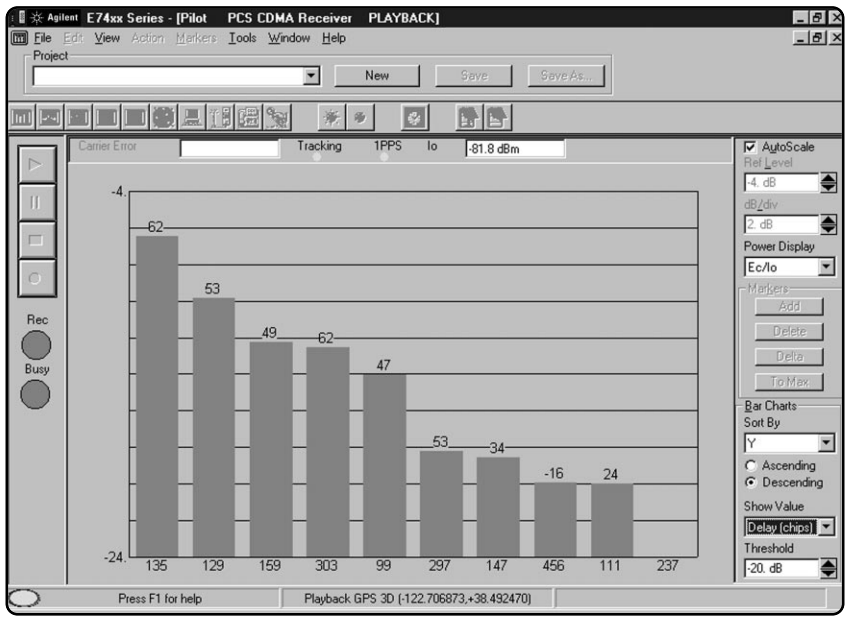


Figure 34. Absolute timing delay measurement using Agilent receiver-based system.

Pilot measurements: absolute timing delay

In addition to measuring the RF levels and pilot pollution interference, the receiver pilot *Top N* and *User List* displays can be used to evaluate timing problems in the network. Since CDMA-based systems are synchronous with GPS timing, any base station timing errors can result in dropped calls. Figure 34 shows the receiver *Top N* pilot display with the bar chart values showing delay in chip units. One chip equals approximately 0.8 microseconds. To measure the base station timing error, the drive-test vehicle must be located near the base station or at a known distance from the base station. Otherwise, the system cannot distinguish between base station timing error and propagation delay. The timing delay measurement can also serve a secondary purpose. Since propagation delay is approximately equal to six chips per mile, the measured delay can provide a quick way to estimate the distance from the drive-test vehicle to the base station being measured. For example, if the delay is 62 chips, the base station is estimated at ten miles away, assuming a direct line-of-sight propagation. Often, a pilot with this excessive delay will not be in the phone's neighbor list or may appear outside the search window of the phone. So the receiver not only finds the missing neighbor pilot, but it also provides the timing delay information that can quickly resolve the source of the problem.

Island cell conditions

Synchronous timing is critical for CDMA networks to work properly. Each base station obtains its timing from GPS for synchronization. When problems occur with the base station timing equipment, network synchronization is compromised. A base station with excessive timing errors can cause an island cell condition. An island cell is a base station with excessive timing errors. For example, suppose a base station with excessive timing errors is serving a subscriber phone. When the subscriber gets close to the cell boundary, the phone is unable to detect any of its neighbors. Recall that the phone gets its timing from the serving cell. Since the serving cell is an island cell, the phone call will most likely be dropped during the hand-off because the timing error is too excessive. The phone searches for neighbor base stations based on their known PN timing offsets. Since the island cell's timing error is excessive, the phone's searcher will look for the neighbor base station within a prescribed timing window and only find uncorrelated noise. This results in a dropped call.

A receiver-based drive-test system is extremely valuable in diagnosing island cell conditions since the receiver can make absolute timing measurements. These measurements are possible because the receiver is connected to GPS and is completely independent of the network. Because a phone-based drive tool derives its timing from the base station, any base station timing errors are transferred to the phone. The receiver is very useful in detecting timing problems before they result in catastrophic consequences. Periodically measuring delay on suspect base stations can provide early warning, allowing corrective action to be taken before it's too late.

Optimizing phone search window settings

As just described, problems such as dropped calls can occur during the hand-off process. Therefore, it is important to make sure that the network timing is continually checked and optimized. In addition, the phone search window settings must be adjusted for optimum performance. The receiver-based drive tool can help optimize phone search window settings by measuring absolute timing delays and by characterizing multipath conditions in the network. (We just described absolute timing, and multipath will be explained shortly.) However, to more fully understand how the receiver can be used for this optimization, a brief explanation of the phone's search process is needed.

Most CDMA phones include three rake receiver fingers and one searcher finger. (Newer phones with six rake fingers are now being introduced. The following description is just an example, and not all phones operate this way.) The searcher finger searches for energy in the active, candidate, neighbor, and remainder sets. The active set takes highest priority in the search process. For example, the searcher looks for the pilot channel of the first base station in its network-provided active set list. Then, it finds the second base station pilot in its active list, followed by the third active set base station pilot. Then it searches for the first candidate pilot. Candidates have the same priority as active pilots. After searching for the active and candidate pilots, the searcher looks for the first base station pilot in its neighbor list. Then it searches the active and candidate set once again. Next, it searches for the second base station pilot in its neighbor list, and so on. After searching the entire neighbor list in this manner, it looks for the first base station pilot in its remainder list.

The phone searcher finger has a narrow window of time over which it searches for pilots. This is called the search window setting. This setting is input at the network switch and transmitted over the air from the base station to the mobile phone via the forward link messaging. Since the timing of each base station's pilot is offset by some multiple of 64 chips from the previous one (determined by the PN increment), the phone needs to search over a small subset of all possible delays of this short code. Note that the search window for the active, neighbor and remainder sets can be set differently. Normally the active set search window is set narrower because the base stations are closer to the subscriber's phone, corresponding to smaller values of propagation delay. In addition, the search window can be set differently for each base station sector. In summary, the phone searches over a relatively small subset of the entire short code sequence. As described next, the receiver performs a correlation over the entire short code sequence, providing more complete measurement capability.

To determine if search window problems are present, the receiver-based drive system measures the absolute delay of the pilots in the neighbor list. If the delay is greater than the phone search window setting, the phone will not measure the signal because the correlation point arrives outside the window. The point to remember is that this PN is in the neighbor list, and the phone will attempt to measure at that PN position relative to the timing established by the serving sector. However, since timing is offset, the measured amplitude is very low and will appear as a small blue bar on the phone pilot display—say a value of Ec/Io of -31.5 dB, which is the lowest value the phone reports.

(Note that a search window setting problem is different than a missing neighbor problem. Missing neighbors refer to pilots that do not appear in the phone's neighbor list and therefore are not measured. With a search window problem, the phone attempts to measure the signal, but the energy is outside the search window and the call is dropped. See page 35 for more information on missing neighbors.)

Here is an example of a phone search window problem. Suppose PN 3 is the primary serving base station that provides the phone with its timing. Suppose the receiver drive tool measures delays of 5 chips on PN 3, 16 chips on PN 6 and 38 chips on PN 9. The delay is a combination of base station timing maladjustment or drift and propagation delay. The further the drive-test system is from the primary server, the larger the propagation delay. Now, it is important to note that the ideal search window setting for the other active PNs or the neighbor PNs is dependent on the delta between the timing delay measured on the primary server and the timing delay measured on these other PNs.

For example, suppose PN 6 and PN 9 are in the neighbor list. Since the phone gets its timing from PN 3, and its delay is 5 chips, then the delta delay of PN 6 and PN 9 is 11 chips and 33 chips, respectively. If the search window for the neighbor set is 30 chips, the phone will not accurately measure the PN 9 signal because it is outside the search window (33-30=3 chips). PN 9 will appear on the phone pilot display, but its power level will be very low. On the other hand, the receiver-based drive system is not affected by phone search window settings. The receiver measures the correct power level of the received pilot signals and reports the absolute timing delays (comprised of base station timing errors and propagation delays).

What is the ideal search window setting? It depends on the system. For example, a rural system having wide coverage areas and low capacity will result in long propagation delays, so you want the search window setting to be very wide. The downside of wide window settings is that it takes more time for the phone to do the correlation. In rural areas, this is not as much of a problem. In urban areas, you could drop the call due to this excessive delay in searching the neighbor list. Therefore, narrow search windows are chosen for urban areas.

Pilot measurements: characterizing multipath

In addition to measuring absolute timing delays, the receiver-based system can characterize the multipath content of the pilot signal. Multipath includes the multiple components of the same transmitted signal, containing numerous propagation paths due to reflections from hills, buildings, and other types of structures. In addition to evaluating the absolute delay of a pilot signal, it is necessary to understand the multipath characteristics of the signal to correctly optimize the search window settings of a subscriber phone. The phone search window is an interval of time over which the phone searches for pilot signals. If the search window is set too wide, the phone needlessly wastes time trying to correlate power at large delays. If it is set too narrow, any system timing delays could result in the signal being missed.

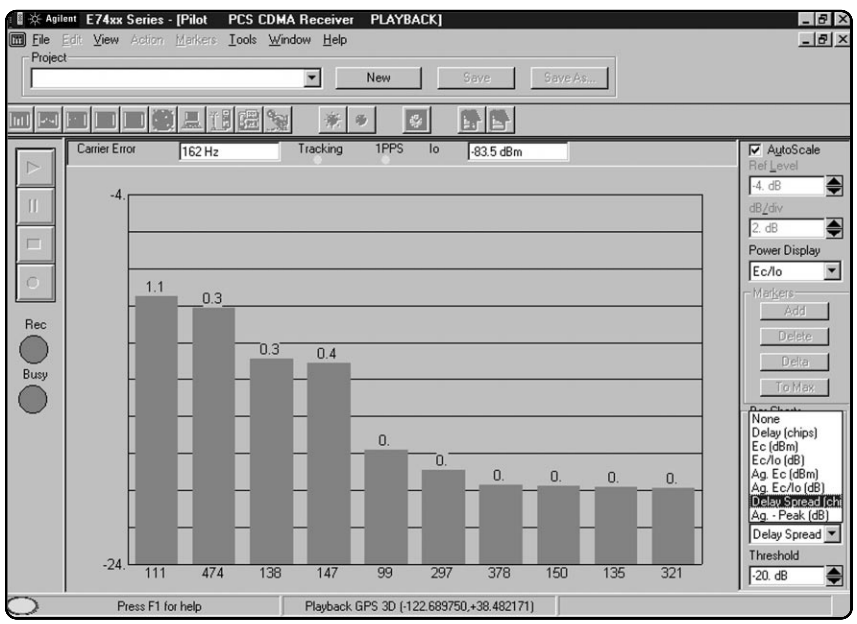


Figure 35. Delay spread measurement, using the E7473A receiver–based system, helps to characterize multipath.

To characterize multipath for properly setting search windows, the E7473A receiver-based solution includes the following measurements: delay spread, aggregate Ec (and Ec/Io), and aggregate - peak Ec (or Ec/Io). Using the *Top N* display shown in Figure 35, the desired measurement values can be displayed by selecting the appropriate *Show Value* function. (Likewise, the *User List* display can be used when viewing a defined subset of the pilots.) The propagation of a base station pilot results in a signal composed of multiple peaks and valleys. The peaks correspond to multipath components that can be utilized by the phone's rake receiver fingers, more so in weak coverage areas. Therefore, it is important to set the phone's search window wide enough to capitalize on these useful multipath components. Earlier it was shown that absolute delay is measured at the highest peak of this signal waveform. Delay spread is a measurement of the time duration over which the significant energy in the entire signal is dispersed, including all the significant multipath components. The delay spread values in chips are shown above each pilot's bar graph.

Several other measurements are also available on this *Top N* display (and *User List* display). Aggregate Ec (or Ec/Io) is computed for a given pilot by integrating the power received over the time dispersion of that pilot. Aggregate - peak Ec (or Ec/Io) is the dB difference between the aggregate Ec (or Ec/Io) and the peak Ec (or Ec/Io). The larger the difference, the wider the energy dispersion caused by the multipath condition. The search window of the phone should be set wide enough to capture the significant multipath components. Recall that CDMA takes advantage of multipath by assigning up to three fingers of the rake receiver to different multipath components of the same signal. This allows low-level signals (which might otherwise not be detected) to be received by the phone.

In summary, absolute timing delay and delay spread measurements made by the receiver-based drive-test system can be used to help optimize phone search window settings and identify island cell conditions. The receiver makes these measurements because it derives its timing from GPS, and thus operates independent of the network.

CW, channel power, and spectrum measurements

The E7473A receiver-based drive tool is useful for network-independent pilot scanning, interference analysis, and timing error analysis. The remainder of this section describes measurements that can be performed using the Agilent receiver-based drive-test system. The functions include CW, channel power, and spectrum measurements.

CW measurements

During the early life cycle of a wireless network, it is necessary to evaluate prospective cell site locations to see if construction of the cell site will provide adequate coverage. To perform this evaluation, a signal generator with a power amplifier is used to transmit CW (continuous wave) signals from the potential cell site. Often the signal generator and antenna are positioned to the approximate elevation of the proposed antennas using a forklift or crane. Then a receiver, with antenna and accompanying collection software, is driven around in a van along the roads in the proposed cell site coverage area. This receiver is usually a dedicated instrument only capable of measuring CW signals. The collected data is exported to a mapping software package and the CW coverage results are evaluated.

Using the E7473A receiver-based drive-test system, both CW and CDMA drive-test measurements can be performed (simultaneously, if desired) using the same hardware. A single compact receiver reduces costs when compared to other systems that require separate receivers for CW and CDMA measurements. Using a narrow, 30-kHz analog filter and numerous choices of DSP filtering, the receiver-based system records CW power as a function of location. CW power is the power at the peak of the transmitted signal. (This is equivalent to placing a marker on a spectrum analyzer trace.) CW power is different than channel power, which is the integrated power in a defined channel bandwidth.

Two CW power functions are available. *CW Power List* allows the user to enter a list of frequencies to be measured. This list can contain both uplink and downlink frequencies. *CW Power Trace* measures the signal frequencies defined by a user-entered start frequency and frequency step size. Figure 36 illustrates the CW power list display.

Channel power measurements

The Agilent receiver-based system can also be used to measure channel power. Channel power is the integrated power within a defined bandwidth. For example, if the channel bandwidth is defined to be 1.25 MHz, the channel power function will measure the power of the entire CDMA channel. Or, if measurements of analog cellular systems are desired, the channel power can be set to 30 kHz. The channel power in a 1.25-MHz bandwidth is equivalent to the Io value displayed in the pilot virtual front-panel display. Two channel power functions are available. *Channel Power List* allows the user to enter a list of channels to be measured. This list can contain both uplink and downlink frequencies. *Channel Power Trace* measures the channels occupying the frequency range defined by a user-entered start frequency and frequency step size.

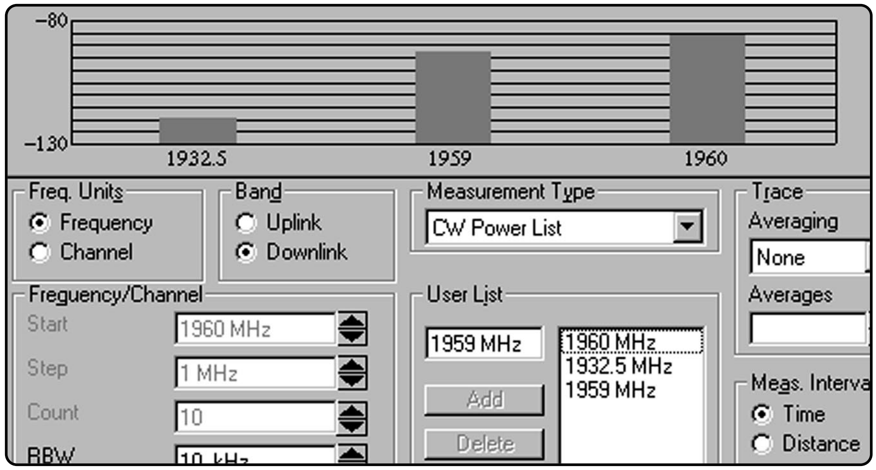


Figure 36. CW power measurements using the receiver-based solution are useful for the site evaluation stage of the wireless network life cycle. Channel power measurements are also available from this same user interface.

Spectrum analyzer display for troubleshooting

The E7473A receiver-based solution also includes built-in spectrum analyzer capability to help optimization engineers troubleshoot problems in the frequency domain. In the past, drive-test solutions relied solely on a phone-based tool. If troubleshooting measurements were desired, a separate spectrum analyzer was required, which added weight and expense to the measurement suite. The E645X is a compact, DSP-based receiver capable of making a core set of spectrum analyzer measurements in addition to the CDMA and CW measurements just mentioned.

Figure 37 is a spectrum display of the entire 1900 MHz PCS downlink band covering the 1930 to 1990 MHz range of the E6450B receiver. The uplink band of 1850 to 1910 MHz can also be viewed. Likewise, another version of the Agilent receiver, the E6452A cellular receiver, can scan the 869 to 894 MHz downlink band and/or the 824 to 849 MHz uplink band. Agilent designed these receivers to maximize the spur-free performance for high-dynamic-range spectrum measurements. For example, internally generated spurious is specified at <–120 dBm, and noise figure is typically less than 8 dB.

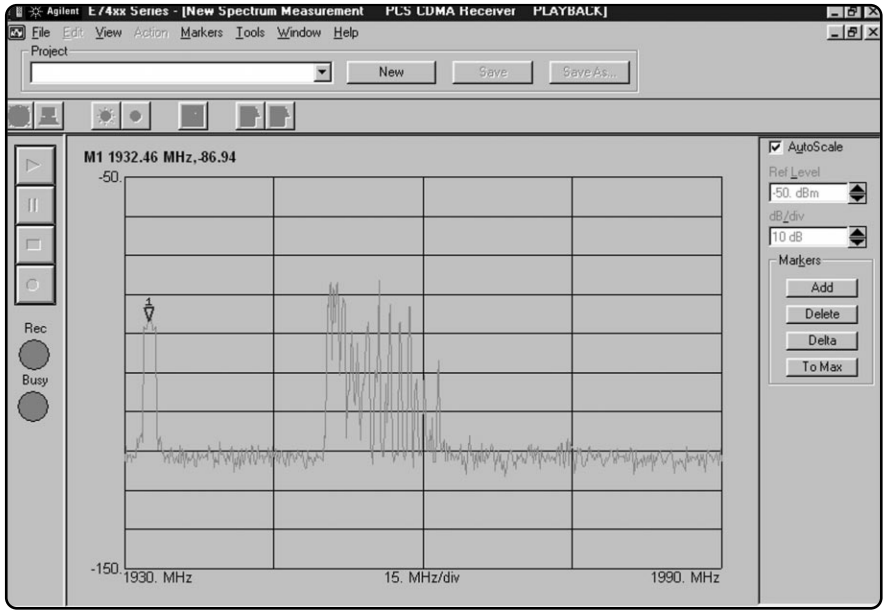


Figure 37. E7473A receiver–based drive-test system with built-in spectrum analyzer capability. A CDMA carrier (with marker) and several GSM signals are shown.

Receiver-based measurement summary

In summary, the multiple functions built into the E7473A receiver-based solutions benefit the drive-test engineer by providing a compact and lightweight design that can be used throughout the network life cycle. This includes site evaluation using CW measurements, to network turn-up and buildout using the network-independent pilot scanning capabilities, to over-the-air troubleshooting using the spectrum analyzer capability.

Section 6: Multiple receiver and phone capability

It is desirable to minimize the number of times a drive-test must be redone. To help accomplish this, the E7473A solution allows multiple receivers and phones to be connected into a single integrated system. As shown in Figure 38, the E7473A can be configured to control up to four phones and four receivers simultaneously. (Refer to the E7473A configuration guide to ensure the correct options are ordered.)

For example, one phone can measure dropped call statistics on the service provider's network while the second can provide similar measurements of the competitor's network. Likewise, multiple receivers can be used to make RF measurements on both networks. This is especially beneficial when comparing networks occupying different bands: for example, one network at 850 MHz and the other at 1900 MHz. Understanding the performance of the competitor's network can help the service provider attract and retain more customers, if results are favorable.

Another benefit of multiple receiver capability is simultaneously measuring multiple carriers on the same network. While one receiver is capable of measuring two carriers in the same band, using multiple receivers provides the speed benefits and the flexibility to operate on independent frequency bands.

Multiple receivers are also useful for monitoring pilot activity at 1900/850-MHz borders, where calls are often handed off from one network to the other. Up to four receivers can be interconnected using serial cables available from Agilent, as shown in Figure 38.

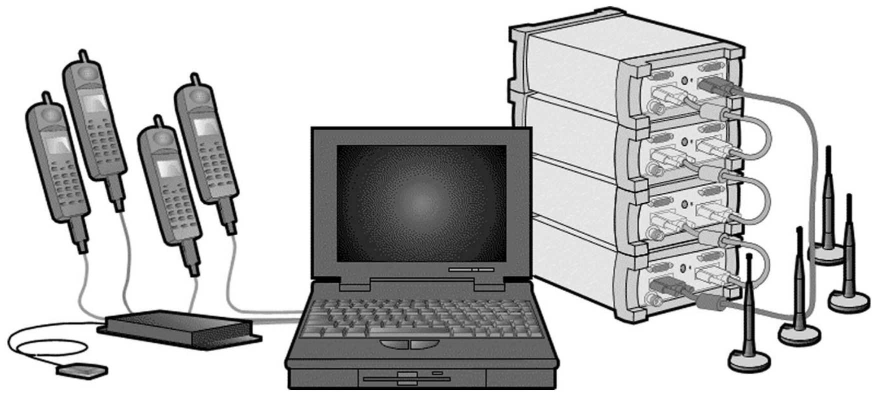


Figure 38. Multiple receiver and multiple phone capability minimizes the number of drives needed to characterize an operator's network or to compare against a competitor's network.

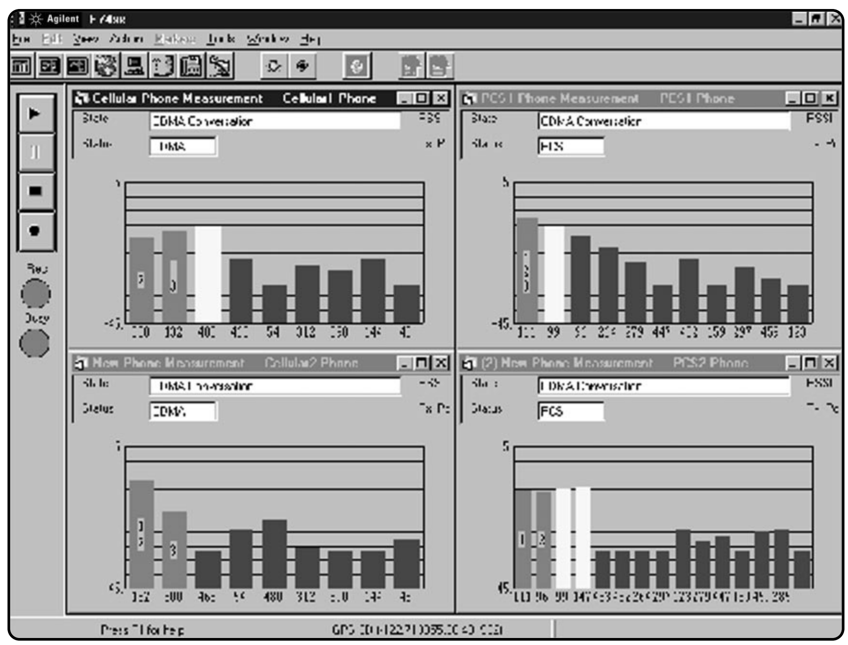


Figure 39. The E7473A Option 150 controls up to four phones. A pilot display for each phone is shown.

As mentioned, with the proper option configuration, the E7473A can control up to four phones. Figure 39 shows four pilot displays, each corresponding to a separate CDMA phone. The phones are interfaced to the PC via optional PCMCIA serial cards. Why multiple phones? The user can make long calls on one phone to measure dropped call statistics, short calls on another to measure blocked calls, and mobile-to-mobile measurements of call origination/termination on the other two phones. (E7473A Option 150 can control up to four phones. Option 100 controls one phone.)

Section 7: E7480A post-processing software overview

Introduction

The optimization process includes drive-testing, post-processing, analysis, and action steps. Post-processing the data that was collected during the drive-test allows the optimization engineer to view this data as a function of location overlaid on street maps. Displaying the data in the context of a map makes it easy to quickly spot the locations of problem areas, especially where blocked calls (access failures) and dropped calls have occurred. Figure 40 shows a display from the E7480A post-processing software with imported street maps. It displays the drive-test data in a variety of formats. For example, the software allows the presentation of the Ec/Io of a specific pilot PN. In this case, PN 474 is chosen from the PN list on the right-hand margin of the display (see highlighted circle). Other parameters such as power by offset - Ec, power by offset - Ec/Io, power by delay, number of pilots, and pilot delta can be selected. Specific events such as dropped calls, blocked calls, and alarms can be displayed to quickly locate problem areas. The E7480A post-processing software was specifically designed for the E7473A drive-test system that consists of either the receiver, the phone, or the integrated receiver and phone. For applications that require multiple phones and/or multiple receivers, the E7480A software provides an easy-to-use interface for selecting and displaying the data.

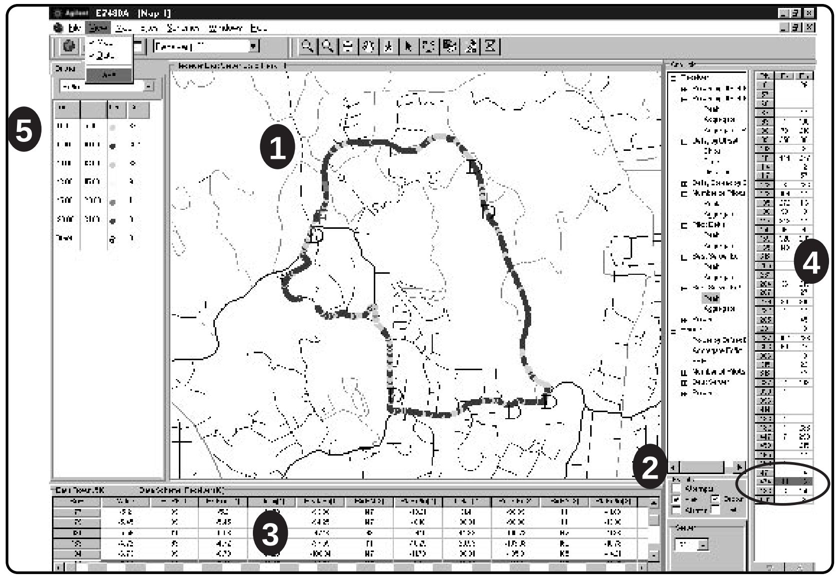


Figure 40. E7480A post-processing software displays the data collected by the E7473A drive-test system. The measured data is overlaid on customer-supplied street maps that are imported into the E7480A software.

Key features of the E7480A post-processing software include the following (refer to the numbers shown in Figure 40):

1. Map view. Street maps can be imported as standard MapInfo *.tab files. Cell sites can be imported as Excel *.xls, comma-delimited files, and tab-delimited files.

2. Events. Event plotting displays call attempts, access failures (blocked calls), dropped calls, and alarms collected and defined in the E7473A CDMA drive-test systems. The dropped calls are displayed in the map above as (D).

3. Data grids. User-defined and selectable data grids display raw data and the value of the selected analysis. These grids can be exported for further analysis.

4. PN list. The PN list shows which measurements were made at each PN offset. You select PNs here for analysis by offset.

5. Legends. User-defined legends display color, range, and symbols of plotted data.

Post-processing can lead to action steps

The next step is to analyze the data and recommend action steps to solve the problems. To help identify the cause of the problems, Agilent drive-test solutions provide the valuable measurement functions and automated alarms described in the phone-based and receiver-based sections of this document.

Depending on the type and extent of the problem, there are several solutions that optimization engineers can consider. For example, if there is a high percentage of dropped calls, the cause could be weak coverage. This is quickly discovered using the Agilent drive-test tools that measure the value of Ec of each pilot. Possible solutions to increase the RF coverage include increasing the power, adding a repeater, or even adding a new base station. On the other hand, if pilot pollution is present, turning up the power will only make the problem worse. Perhaps downtilting the antenna of the offending base stations could solve the problem. If there are missing neighbor pilots (in other words, PNs not in phone neighbor list), one solution is simply to add that pilot to the neighbor list. If it was not intended to have that pilot provide coverage in the area, possible solutions include reducing the power of that pilot or downtilting the antenna.

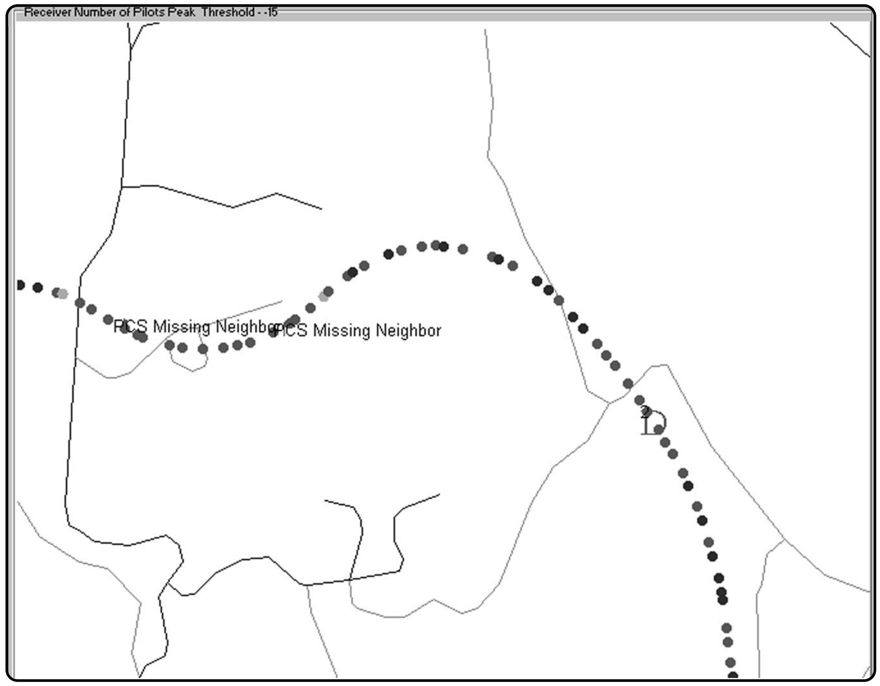


Figure 41. E7480A post-processing software with alarm events indicates missing neighbor conditions

Users of the Agilent drive-test systems have found that an integrated receiver and phone-based tool allows them to tell ‘what’ the problem is and ‘why’ the problem is occurring. Automatic alarm capability in the E7473A provides the operator with immediate notification of problems and causes. Alarms generated in the E7473A collection software can be graphically displayed in the E7480A post-processing software using the *Events* user interface. For example, Figure 41 indicates locations where missing neighbor conditions occurred.

Section 8: Drive-test case studies using the Agilent integrated solution

Problem-solving

These case studies will take the information presented earlier, and help you solve some difficult optimization problems using the E7473A drive-test solutions. Each case study will follow a common methodology.

First, a drive-test is performed using the E7473A integrated receiver-and phone-based drive-test system. Using the extensive measurement capabilities and automated alarms in the E7473A, the causes of problems can often be identified immediately during the drive-testing.

Second, to find solutions to the problems, post-processing of the collected data is performed. The drive-test database is imported into the E7480A post-processing software. Customer-supplied street maps (.tab files) are also imported into the post-processing software to enable viewing of the data in relation to the drive-test route. The *Events* feature of the software shows the locations where the dropped calls, blocked calls, and alarms occurred. This step enables you to tell *what* the problem is, but it has not answered *why* it happened.

Third, the case study will provide more in-depth explanations of why the problem occurred. This is where the receiver-based measurement data plays a vital role. The receiver can determine if the problem is due to poor RF coverage by measuring parameters like Ec, Io, Ec/Io. Another problem source could be a high level of interference. Plotting the number of pilots above a threshold on the post-processing software display can indicate pilot pollution problems. Examining fourth, fifth, and sixth-pilot delta can add further credibility to the pilot pollution diagnosis. (Details of these measurements will be described in the case studies that follow.) Another potential problem that is discovered with the receiver is the missing neighbor condition. Quickly diagnosing this problem requires having an integrated drive-test tool with a common database to compare the pilots measured by the phone and the receiver. This fast problem-solving capability is further enhanced and simplified by the use of alarms built into the E7473A solution.

The following table lists the case studies that will be presented in this section. The page numbers for each case study are included for your easy reference.

Case study list

Case Study #1: Poor RF coverage

The first case study helps us understand the cause of dropped calls at several locations. With typical phone-based solutions, the Ec/Io is measured at each location to get an indication of the RF coverage. At first glance, the Ec/Io is reasonable at approximately -10 dB, so it does not indicate an RF coverage problem. So, why are the dropped calls occurring? Is it interference? Or could it still be an RF coverage problem?

Refer to the Agilent E7480A post-processing software display in Figure 42. The measurement data was collected by the E7473A integrated receiver- and phone-based drive system. The receiver measures the Ec/Io of the best server at each location along the drive route. The best server measurement data set is selected and shown highlighted on the right. The legend of the Ec/Io values is shown on the left. (The actual software displays the data and legend in color.) Note that several dropped calls were detected by the phone, as indicated by the “D” on the map. Why did the drops occur?

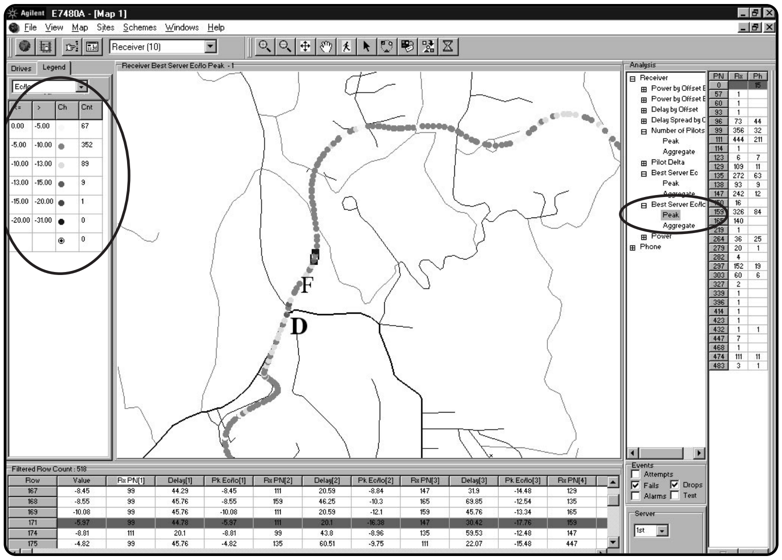


Figure 42. E7480A post-processing software indicating best server Ec/Io data and dropped call events.

By changing the best server selection from Ec/Io to Ec in the analysis area, the displayed data and corresponding legend now appear as seen in Figure 43. The *Plot Labels* function displays the PN offset value of the best server base station pilot signal at each location. Note that the Ec values at the locations where the dropped calls occurred are below –110 dBm. So, even though the Ec/Io was approximately –10 dB, it did not tell the whole story. The low best server Ec values indicated that the RF coverage was indeed the cause of the dropped calls. Since the Agilent receiver can make simultaneous measurements of Ec and Io (and consequently Ec/Io), these parameters can be individually viewed in the post-processing software to determine the root cause of many network problems. Phone-only solutions do not make simultaneous Ec and Io measurements, so it is often difficult to know whether low Ec/Io conditions are the result of low Ec or high values of Io.

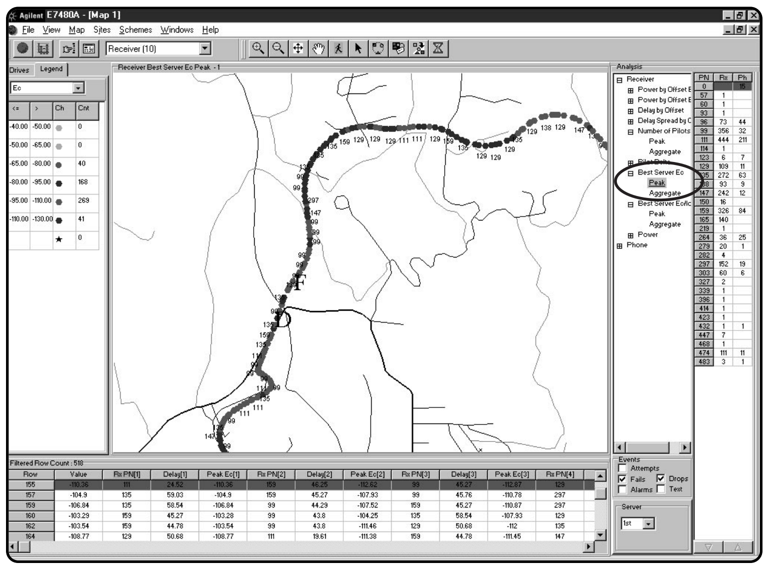


Figure 43. E7480A indicating best server Ec and PN offsets for each value.

Various E7473A measurement displays will be shown with each E7480A post-processing display in each case study. This should help you understand which measurements were used to generate the corresponding post-processing displays.

Case Study #2: Pilot pollution

Case study #2 begins with the phone-based drive-test tool reporting high FER (frame erasure rate) that tells *what* the problem is, but not *why* it happened. Figure 45 is a post-processing display of a drive-test where the phone FER is displayed on the map, and the measurement detail is shown in the data table.

The phone does not measure all the pilots in a network. It receives a subset of the total pilots in a neighbor list that is provided by the network. Since the receiver is independent of the network, it measures all the pilots received at its input. The post-processing software is used to display the *number of pilots* measured by the receiver at each data point. Refer to Figure 46 to see a sample receiver measurement shown in playback mode. The *Top N* display includes five pilots above a threshold of –15 dBm.

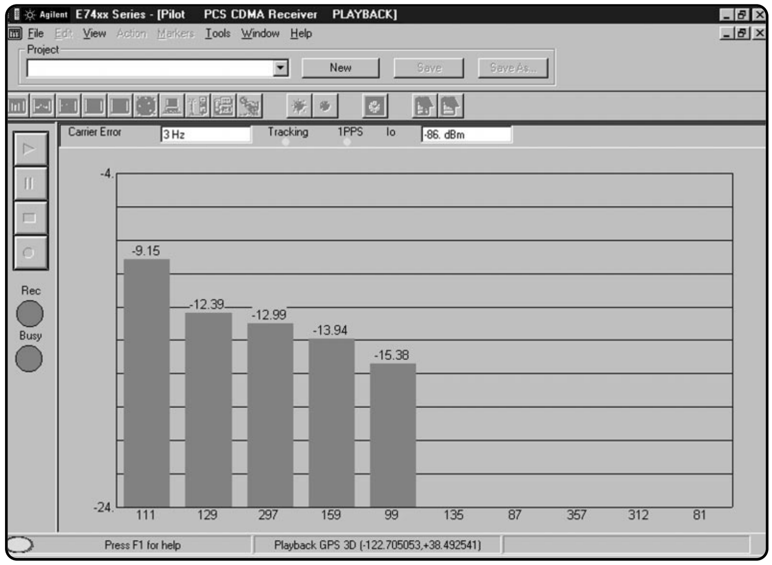


Figure 44. E7473A drive-test software. Playback mode shows Top N display corresponding to a measurement event selected in the E7480A post-processing software. Low values of Ec indicate poor coverage.

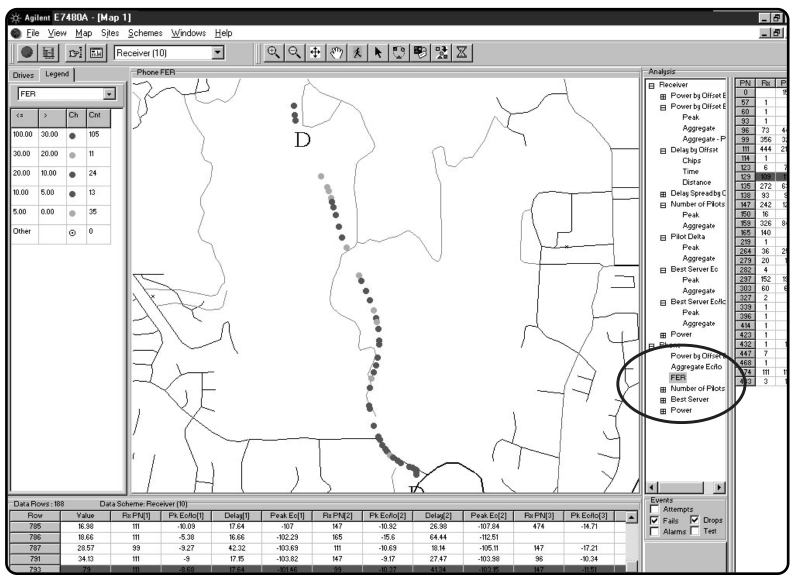


Figure 45. Post-processing software showing FER display.

The five pilots just shown are represented as a single data point on the post-processing display in Figure 47. The threshold can be adjusted by entering the value in the entry window in the bottom right corner.

The cause of the high FER problem in this example is pilot pollution. More than three significant pilots can cause problems with a CDMA phone because its built-in rake receiver circuitry has three fingers to demodulate the active signal. By examining the post-processing display and the data grid, the specific interfering pilots can quickly be identified.

Another useful post-processing feature that relates to pilot pollution is the *4th pilot delta* function. Since pilot pollution results from having more than three pilots of significant amplitude value, it is often the fourth highest pilot that causes many pilot pollution problems. In an ideal network, the fourth highest pilot should be at least 6 dB below the highest pilot. This difference between the fourth and the first pilot is known as 4th pilot delta. In the example in Figure 48, the 4th pilot delta is 1 or 2 dB in areas where the FER is also high. Low pilot delta can cause high active set churn and slow hand-offs, which often leads to high FER and dropped calls. Analysis of subsequent pilot deltas (for example, 5th, 6th, etc.) can also be performed using the E7480A post-processing software to determine if even worse problem conditions are present.

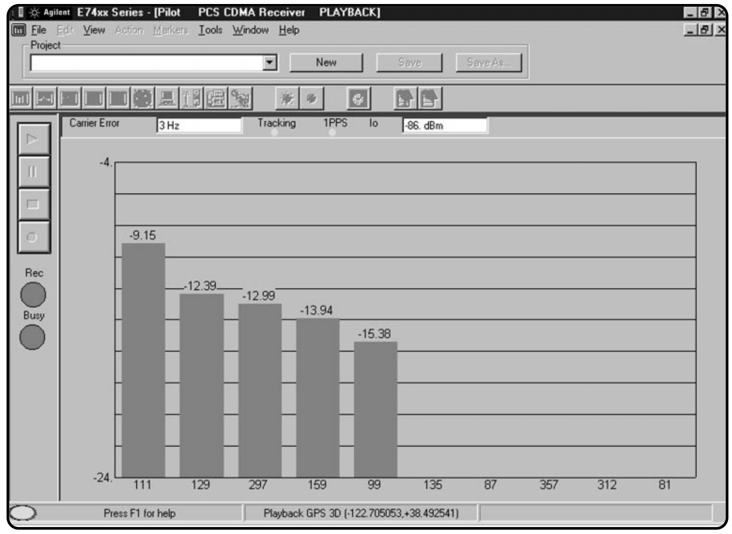


Figure 46. E7473A drive-test software. The Top N pilot display shows five pilots above a threshold, resulting in pilot pollution.

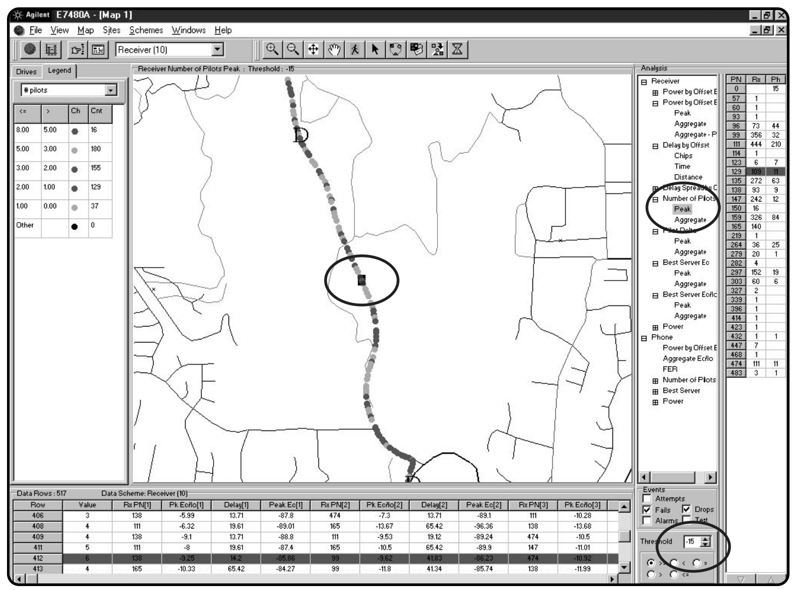


Figure 47. Post-processing software. The number of pilots selection is used to identify pilot pollution.

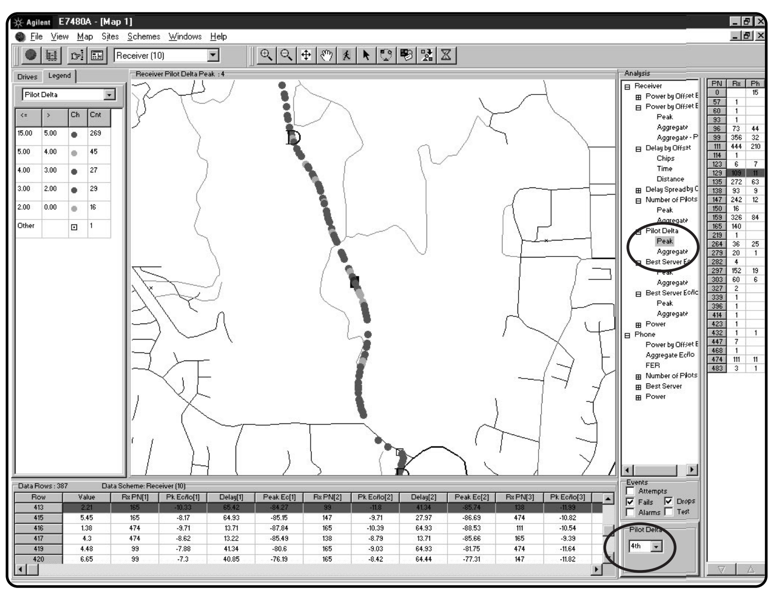


Figure 48. Post-processing software indicating a low 4th pilot delta causing high FER.

Case Study #3: Missing neighbor

The goal of the third case study is to resolve a common optimization problem—missing neighbors. Here is one example that illustrates an effective means of automatically detecting a missing neighbor problem. Using the alarm capability in the integrated phone- and receiver-based Agilent E7473A drive system, the software can automatically alert the operator that a missing neighbor condition exists. The alarm indicator can be shown in both the E7473A software and the E7480A post-processing software, as seen in figure 49. The automatic alarm indicator tells the operator which PN is missing, so the problem can be quickly detected during the drive-test rather than at the end of the day or several days later. The data can be played back in the E7473A software to provide additional graphical detail to the map-based post-processing software. PN 129 is the missing neighbor pilot. It happens to be the strongest pilot in the area, despite the fact that its delay is measured to be 55 chips away (approximately 9 miles of propagation distance). Although not shown here, the post-processing software could display *delay by offset* and *power by offset* for PN 129.

Here is another example that illustrates how the E7480A can provide additional insight into the missing neighbor problem. The symptom typically shows up as high FER or perhaps even as a dropped call, as indicated by the "D" event markers in the post-processing display in Figure 50. With the FER analysis phone measurement selected, the data displayed on the map shows the values of FER along the drive-test route. Why is the FER so high? Why did the dropped call occur?

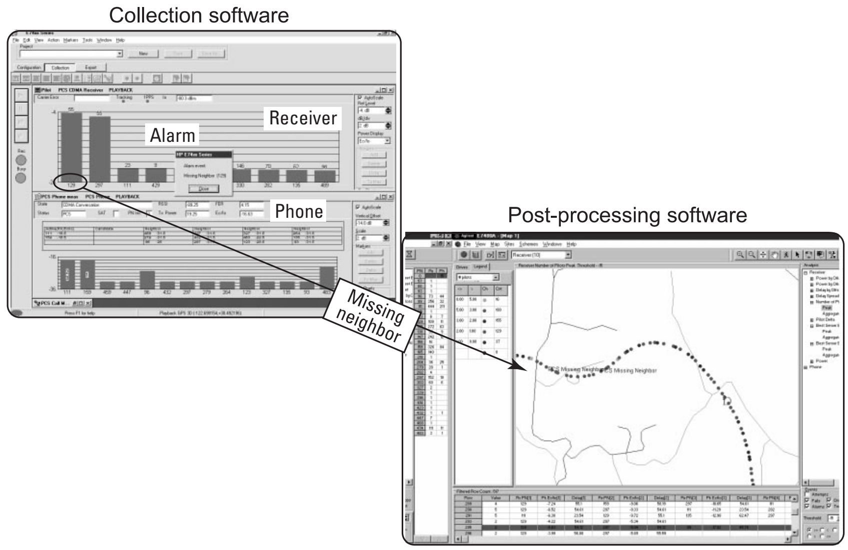


Figure 49. Alarms reveal missing neighbor problem in both the E7473A collection software and the E7480A post-processing software. The actual PN offset of the missing neighbor pilot is displayed on the E7473A to immediately alert the operator.

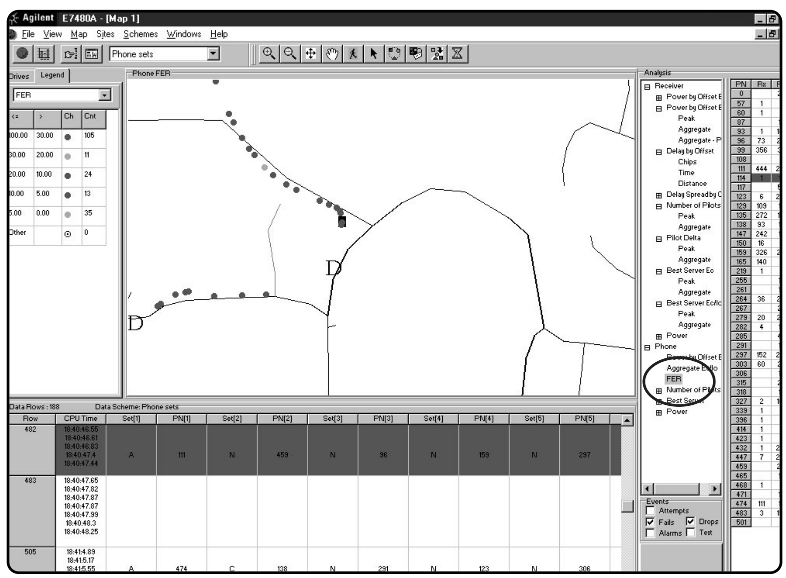


Figure 50. Post-processing software indicating dropped call events on the map display.

Phone-based drive-test tools are used to verify that a dropped call occurred in the location reported in the subscriber's complaint. As briefly described earlier, the phone searches for pilot signals that are in its neighbor list. The neighbor list is continually being updated by the network as the phone travels throughout the network. The base station transmits this list to the phone over the air interface. The problem with using a phone-only-based drive-test system is that it falls prey to the same network problems that it is trying to resolve. What is needed is a network-independent drive-test solution. The Agilent receiver-based drive tool was specifically designed to overcome this problem. Since the receiver uses GPS to synchronize its timing, it does not need to be tied to the network. Furthermore, it scans all 512 pilots, rather than being limited to the neighbor list as a phone is.

Figure 51 shows the receiver pilot display and the phone pilot display. The receiver measures a high-level pilot with PN 474, while the phone does not. Note that PN 111 has a lower amplitude than PN 474.

If the *power by offset, Ec/Io* receiver-based measurement is chosen in E7480A post-processing software, selecting PN 474 will show a high level of Ec/Io around the drop area. Refer to Figure 52. If this PN were included in the neighbor list, the call would not have been dropped. If desired, the neighbor list of the phone could be viewed by scrolling the data grid under the point where PN 111 is active. Recall that PN 111 was assigned to the call prior to the drop. The data grid would show that PN 474 is not included in the neighbor list.

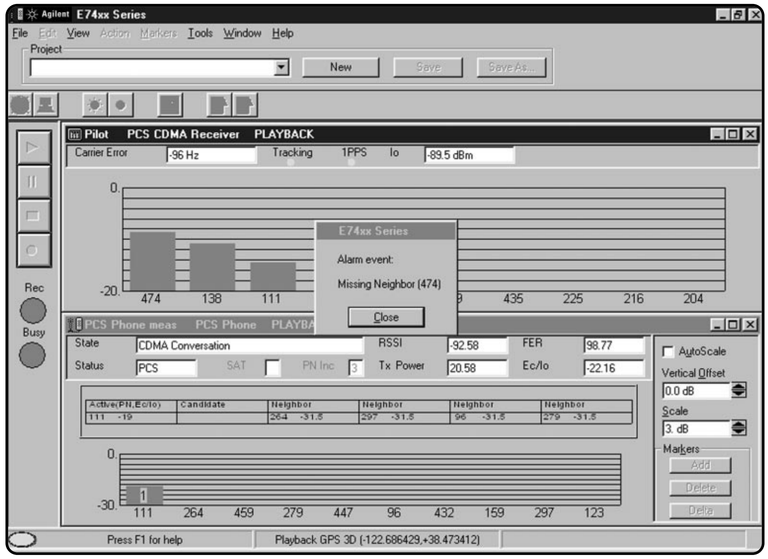


Figure 51. E7473A drive-test software showing missing neighbor; PN 474 is measured by the receiver, but not by the phone.

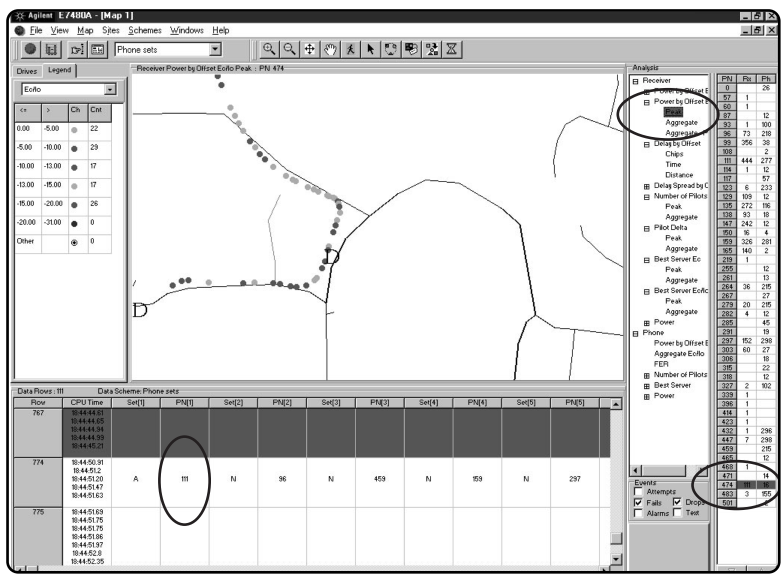


Figure 52. E7480A post-processing software indicating power by offset using PN 474 (missing neighbor).

Case Study #4:
Phone search window settings

Case study #4 explores the problem of search window optimization of the phone. If the search window is not set properly, dropped calls can once again result. A phone-based drive-test system can verify that the calls are being dropped. However, a receiver-based tool is used to determine why they are dropped.

The phone searcher finger has a narrow window of time over which it searches for pilots. This is called the search window setting. Since the timing of each base station's pilot is offset by some multiple of 64 chips from the previous one (set by the PN increment), the phone needs to search over a small subset of all possible delays of this short code. Note that the search window for the active, neighbor and remainder sets can be set differently. To determine if neighbor list search window problems are present, the receiver-based drive system measures the absolute delay of the pilots in the neighbor list. If the delay is greater than the phone search window setting, the phone will not accurately measure the signal because the detected signal arrives outside the window. A dropped call can result. If the windows are set too wide, the phone takes too long to search and calls can be dropped. (refer to page 23 for a detailed description of phone search window settings.)

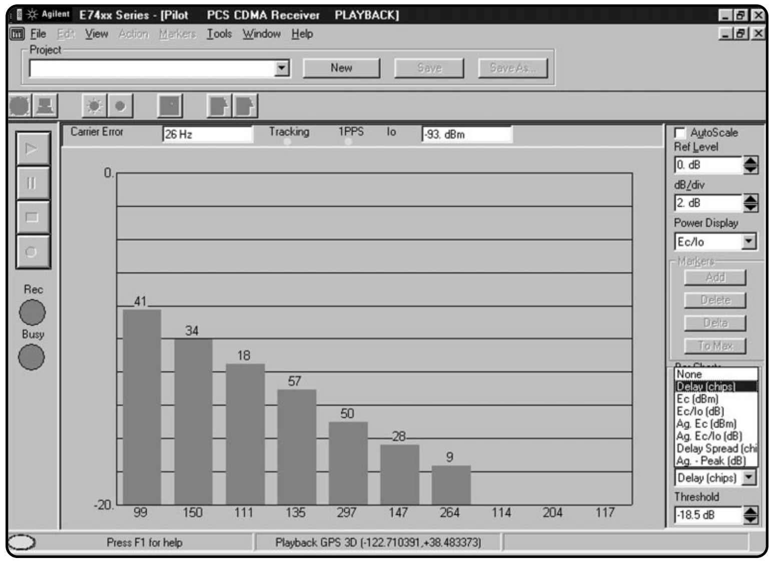


Figure 53. Receiver "Top N" display of absolute delay can be used to help optimize phone search window settings.

Figure 53 illustrates how the receiver-based drive-test tool measures the absolute delay of each pilot signal. Delay is measured in chips, a unit of measurement equal to 0.8 microseconds (the reciprocal of 1.2288 Mchips/sec).

In addition to absolute delay, the receiver can characterize the multipath on each pilot signal by measuring delay spread (in chips) and aggregate minus peak Ec/Io (in dB). (refer to page 23 for more details about multipath and its effect on search window settings.)

Using the E7480A post-processing software, its graph window feature offers another view of pilot delay and delay spread that enables optimization engineers to properly set phone search windows. Initially, the FER measurement data in the area surrounding the dropped call is selected. Figure 54 indicates that PN 111 is the only active pilot in the data grid. The *select area* pointer is used to select data where PN 111 is the active set PN, corresponding to the area surrounding the dropped call. This data will be used later to graphically display the absolute delay and delay spread.

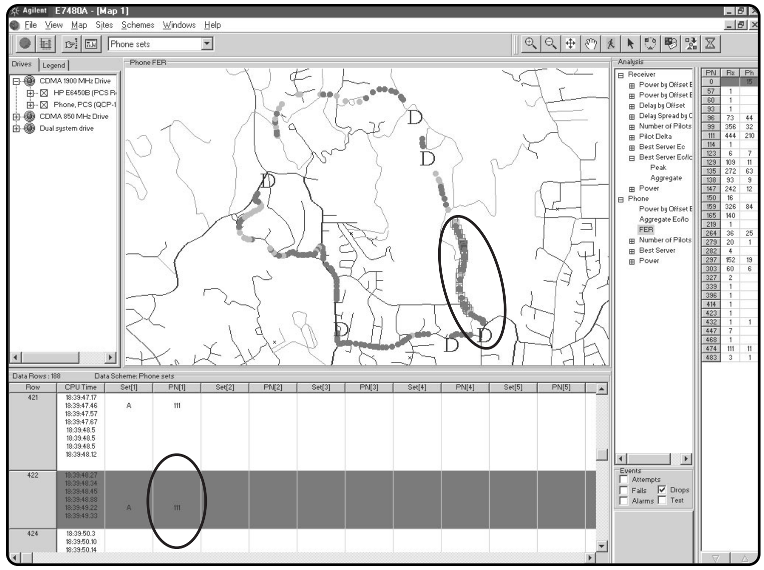


Figure 54. Post-processing software showing the selected area around the dropped call event, for graph analysis.

Figure 55 illustrates that a graph window is opened in the post-processing software to plot PN 111 *delay by offset* and *delay spread by offset*. The PN count list at the right side of the window is used to select PN 111. Since the phone's timing is derived from the primary serving base station, the search window settings are delayed relative to the absolute delay of the best server, represented by PN 111 in this example.

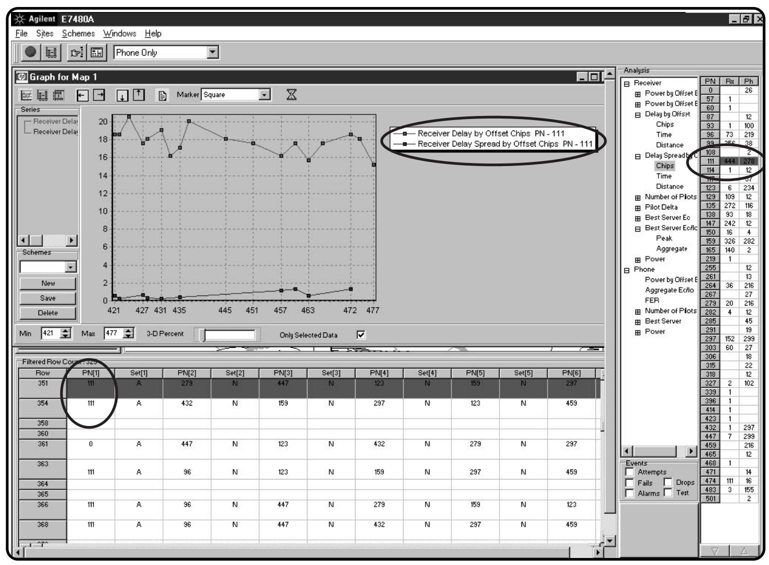


Figure 55. Post-processing software shows how the graph window displays absolute delay and delay spread for PN 111 to help characterize multipath and optimize the phone search window setting.

In summary, incorrect phone search window settings can result in dropped calls. By using the receiver-based drive-test tool, absolute delay and multipath can be characterized to optimize search window settings.

Case Study #5:
Competitive comparison

The final case study illustrates how the multiple receiver and phone capability of the E7473A drive-test systems can help compare competitive CDMA networks. In contrast to the earlier case studies, this study provides CDMA wireless service provides with the framework to compare their network performance with that of a competitor, using the displays available from the E7480A post-processing software. Providers can perform comparisons of coverage, pilot pollution, timing delays, and many other parameters using multiple phones and receivers. Figure 56 shows a display of two CDMA networks, one in the 850 MHz cellular band and the other at the 1900 MHz PCS band. With the multiple receiver and phone capability of the Agilent drive-test solution, only one drive is required to collect measurement data of multiple networks. (refer to page 28.)

Figure 56. Post-processing software showing a competitive comparison of two CDMA networks.

Conclusion

We have demonstrated how the E7473A drive-test systems and E7480A post-processing software can help wireless service providers and network equipment manufacturers quickly optimize their CDMA networks. Based on an integrated receiver and phone approach, the E7473A solutions benefit the optimization engineer by telling "what" the problem is and "why" it happened. This reduces the resources required and minimizes the time needed to optimize networks, resulting in financial savings to the wireless company.

This product note illustrated how the Agilent drive-test and post-processing solutions can help you reduce overall operating costs by locating problems more quickly than with other available solutions. Alternative drive-test systems that are based solely on a phone often leave problems unresolved or may require many additional drives to finally resolve issues. Unresolved problems can lead to poor quality of service and ultimately to customer turnover.

The examples shown in this product note illustrated a subset of the capabilities of the Agilent drive-test and post-processing tools. For more information, contact your Agilent sales representative to learn more about the growing line of drive-test products.

Related literature

• 5968-5555E
E7473A CDMA Drive-Test System Technical Specifications

• 5968-5553E
E7473A CDMA Drive-Test System Configuration Guide

• 5968-1549E
CDMA Post-Processing Product Overview

Web-based information

Refer to the following web site for more information on the Agilent family of drive-test systems.

www.agilent.com/find/drive_test

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Printed in USA 05/00
5968-5554E

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