

CDMA Forward Link Coverage Field Testing, Part II



by

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Abstract

The use of CDMA field testing equipment, introduced in Part I, data collected by the equipment in the field and analysis is presented here in Part II. CDMA system parameters and performance are measured primarily by signal to noise ratios (e.g. E_c/I_o) instead of signal strength (dBm) and frequency re-use has been replaced by code re-use patterns. The CDMA field testing equipment has many advantages over carrier wave (CW) coverage propagation analysis because it uses pseudo noise (PN) modulation, measures neighboring transmitters with PN time offsets and measures multipath from the local transmitter and neighboring transmitters all in E_c/I_o . The system is based on the CrocodileTM transmitter, the Super EagleTM pilot scanner and TECC software.

1. Introduction

It is the authors' experience that most CDMA system designers make use of tools designed for FDMA or TDMA systems. Typically, the tools and methods employ CW transmitters and receivers for propagation analysis that can only measure signal strength in dBm. Part I of this article presented the hardware system suitable for propagation analysis that can measure E_c/I_o in dB. E_c/I_o is the CDMA specific measurement of choice for the forward link. This is the ratio of the energy

of the pilot signal being measured to the total power in the channel. The total power in the channel includes the pilot signal being measured, pilots from other Base Stations (BSs), traffic and other channels from the BSs and noise.

The hardware consists of the BVS Crocodile™ CDMA transmitter and the BVS Super Eagle™ PN scanner. The Super Eagle completes a scan of all 512 PN offsets at a real time rate of 26.67 ms and reports the E_c/I_o (dB) and correlated power (dBm) in $\frac{1}{2}$ chip increments to the recording laptop computer. The regularity and frequency of the Super Eagle's reporting make it a powerful tool for neighbor list verification, detection of PN confusion, PN pollution and corrupted CDMA spectrum in an operating CDMA network. The Super Eagle, used in combination with the BVS Crocodile PN transmitter provide a true "apples to apples" or E_c/I_o validation of site coverage prior to cell construction.

Following, after the review of CDMA terminology, are actual examples of processed Super Eagle PN scanning measurements intended to illustrate the capabilities of the device and advantages of testing with modulated waveforms.

2. Review of CDMA metrics and CDMA time

Pilot coverage from neighboring BSs must overlap in fringe areas to accommodate hand-off. However, the overlap should not be excessive or have a large number of BSs in the same overlap. Each BS that has significant power in the overlap area will raise I_o , decrease E_c/I_o and capacity and quality will suffer in the geographic area. This is known as Pilot Pollution or PN Pollution.

Each CDMA BS transmits a pilot code to aid the handset with demodulation and to measure BS strength. The pilot code is actually the same for each BS, but the PN Sequence Offset specifies the delay between the Global Positioning System's (GPS) even second tick and the start of the PN code sequence.

Each BS has a PN sequence Offsets that is a multiple of the chip rate times 64 ($1/1.2288 \text{ MHz} \times 64 = 52.1 \text{ mS}$). If the propagation delay between the BS and the handset is greater than 52.1 mS and E_c/I_o is significant, PN Confusion can occur. Unlike the Super Eagle PN Scanner, the handset does not have a GPS receiver or the absolute system time. The handset uses relative time. If the handset is demodulating a BS and goes to measure another (new) BS, the handset calculates the nominal position, in time, of the new BS relative to the current BS being demodulated. The handset then searches around the nominal position with-in a Search Window. If PN Confusion occurs, the handset may not be able to find other BSs.

3. Field Testing

For an existing network, the BVS Super Eagle provides a real-time spot check of the serving PN offsets and additional PN offsets in the area (see Figure 1). The engineer can apply the results of the drive test to look for PN pollution as well as neighbor list development/verification. The engineer can observe general trends in the pilot quality during drive testing to obtain a feel for the overall network performance. Figure 1 shows a single pilot greater than T_ADD , two pilots greater than T_DROP , and seven additional pilots of insufficient quality to provide service. The seven remaining pilots act as interferers to the three strong pilots. The solution in this case would require a change in the RF environment that could include reductions in power, antenna downtilt or changeouts, or possibly reduction in antenna heights of the interfering transmitters. Typical CDMA measuring

equipment that relies on commercially available subscriber units would generally only provide indication of the three strongest PNs.

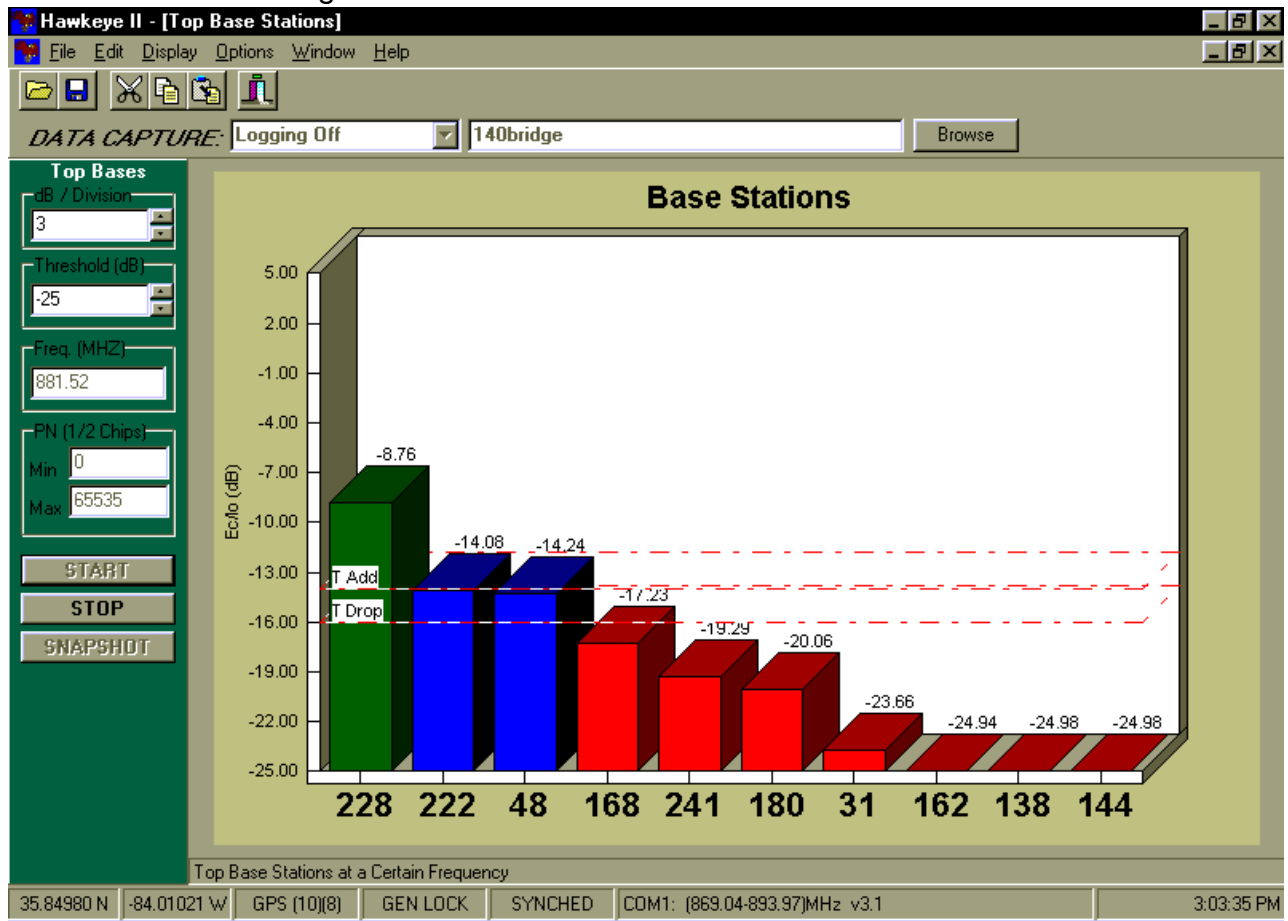


Figure 1: BVS Super Eagle Top Ten Base Stations Real Time Display

A comprehensive verification of a neighbor list in an existing system may be accomplished by post processing data collected in a dedicated drive test. Figure 2 is the PN offset assignments within a dense urban environment of a major metropolitan city with an 850 MHz IS-95 overlay network. The histogram is the result of post processing software custom developed for the Super Eagle by TEC CELLUAR, TECC. The data shown was collected within a five square mile area and is illustrative of general PN pollution and the affects of PN offset reuse.

For the case of general PN pollution we only need to consider the substantial number of PN offsets serving the area. Detection of PN pollution by typical commercially available CDMA measurement equipment would be less likely due to the reliance on subscriber units capable of tracking a maximum 4 PN offsets at a time with a limited scan capability.

Dense Urban Environment PN Assignments

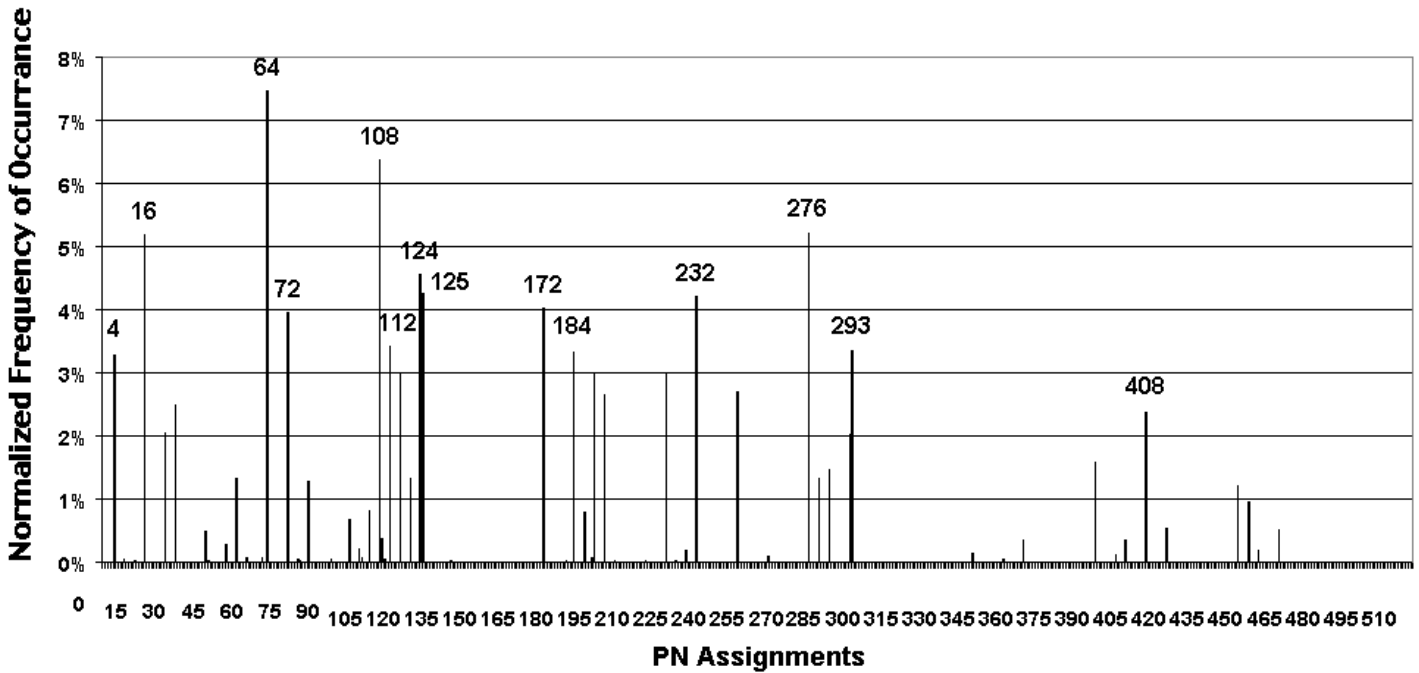


Figure 2: Dense Urban Environment PN Offset Assignments

Also shown in Figure 2, is PN offsets 124 and 125. The PN reuse pattern of the system was based on an increment of 4 and therefore PN 125 was not assigned. The detection of PN offset 125 is most likely associated with a transmitter using PN 124 that is between 9.6 and 19 miles away. Conditions such as this may result in misdirected handoff (dropped calls), access failures (blocked calls), and a general reduction in the overall quality of the call. The solution to this problem is found in serious inspection of the RF configuration of the “confusing” PN (generated by a BS or Crocodile transmitter).

For the same area driven, the mean E_c/I_o of the statistically significant serving PN offsets was given to be -13.63 dB with a corresponding correlated power of -62.74 dBm. Applying the custom post processing software developed by TECC to data collected by the BVS Super Eagle in other area types of various networks allows for a quantitative comparison of the non linear relationship between pilot channel quality and correlated power as shown in Table 1. These results may be used to support the need for using modulated waveforms for CDMA site validation instead of CW signals.

Table 1: Comparison of E_c/I_o vs. Correlated Power for various area types

Correlated Power (dBm)	Signal Quality	E_c/I_o (dB)
Dense Urban	-62.74	-13.63
Urban	-68.32	-11.42
Suburban	-87.74	-13.65
Rural	-84.55	-12.04

The PN offset histogram post processing function may also be used to detect spectral corruption by reporting non-zero frequency of occurrences for all 512 PN offset as shown in Figure 3. By judiciously setting the minimum E_c/I_o threshold 2 to 3 dB above the general noise floor, spectral corruption may be easily detected in areas of poor CDMA coverage and areas of gross narrow band interference.

Suburban PN Assignments

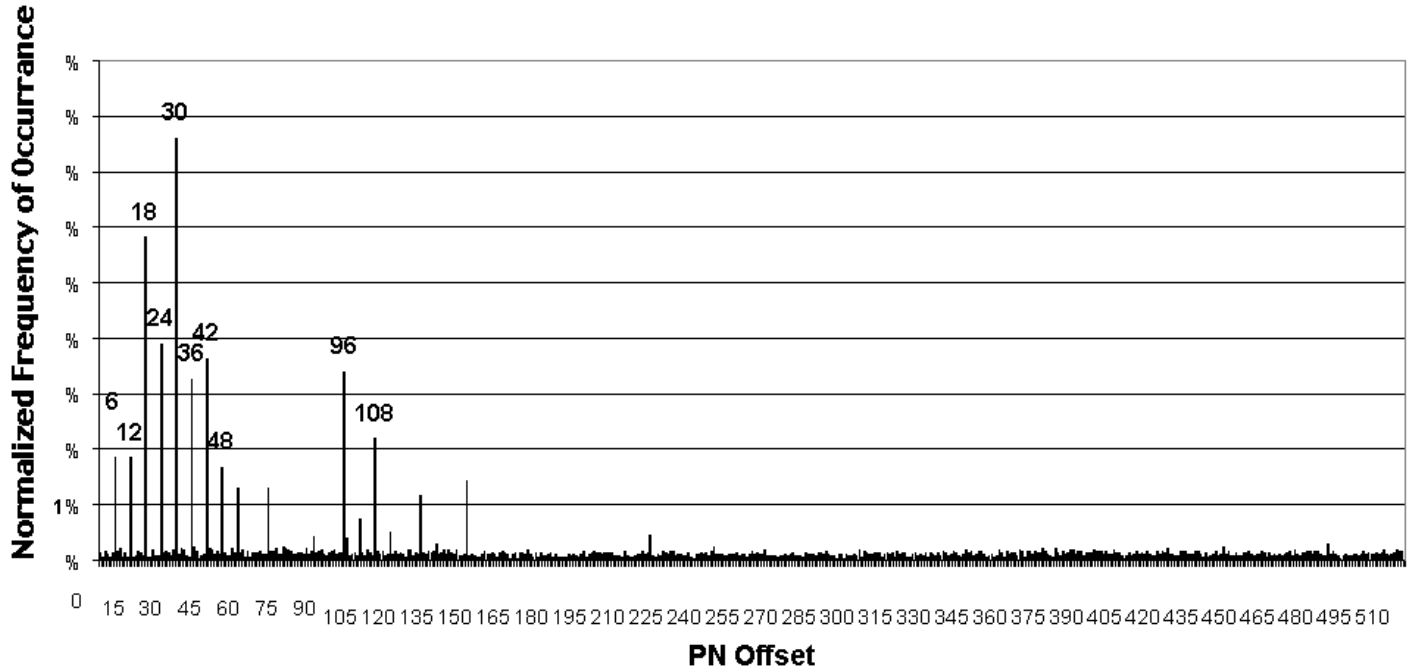


Figure 3: Example of PN Count Analyses showing CDMA spectral corruption

The benefits of modulated waveforms over CW, in the validation of CDMA sites can be shown by examination of scatter plots (figure 4) showing the general decay over distance of E_c/I_o and correlated power as measured by the Super Eagle. Created from Super Eagle data post processed using custom developed software, Figure 5 provides an indication of uncorrelated variability of pilot channel quality (E_c/I_o) to the received power of the measurement. Figure 5 shows that an E_c/I_o of -15 dB can occur for received power levels between -65 dBm and -110 dBm. Strong signal strength does not always indicated strong E_c/I_o levels! What is clear from these figures is that signal strength alone has less significance in placing, validating, or troubleshooting cell site locations.

Ec/lo & Correlated Power vs Distance

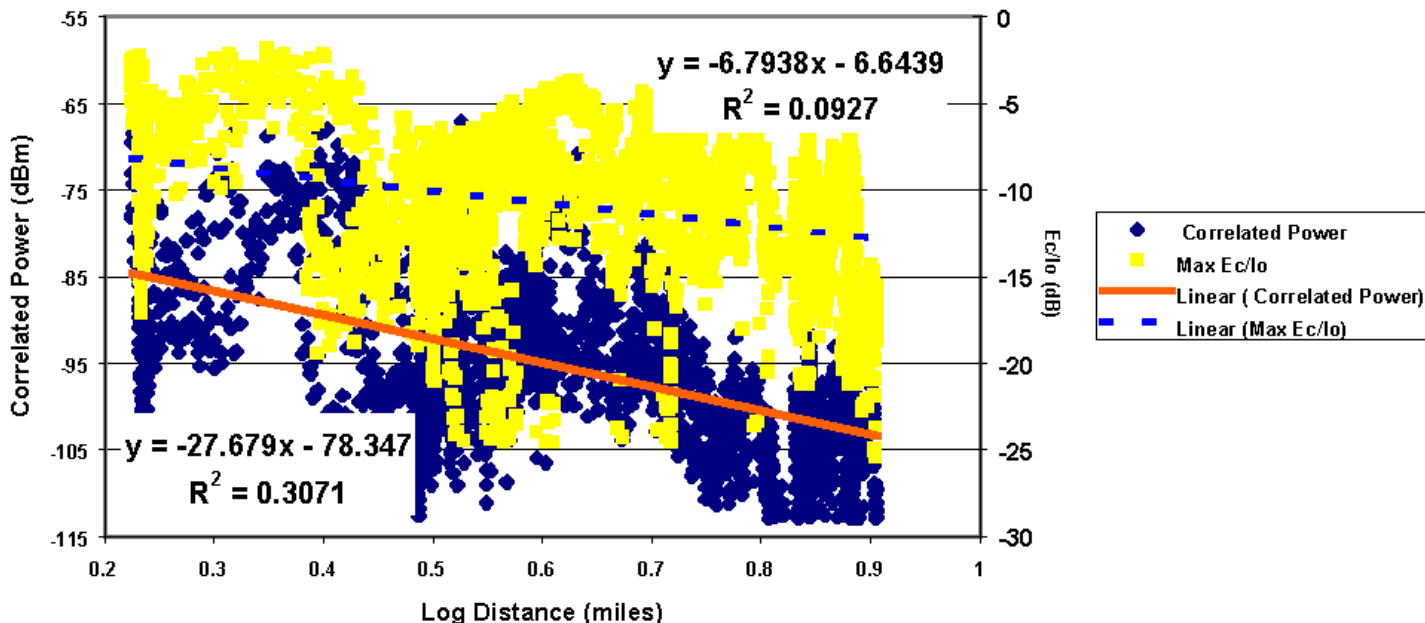


Figure 4: Scatter plot showing Ec/lo and Correlated Power vs Distance.

Ec/lo vs Correlated Power
Correlation Coefficient, $R = 0.56$

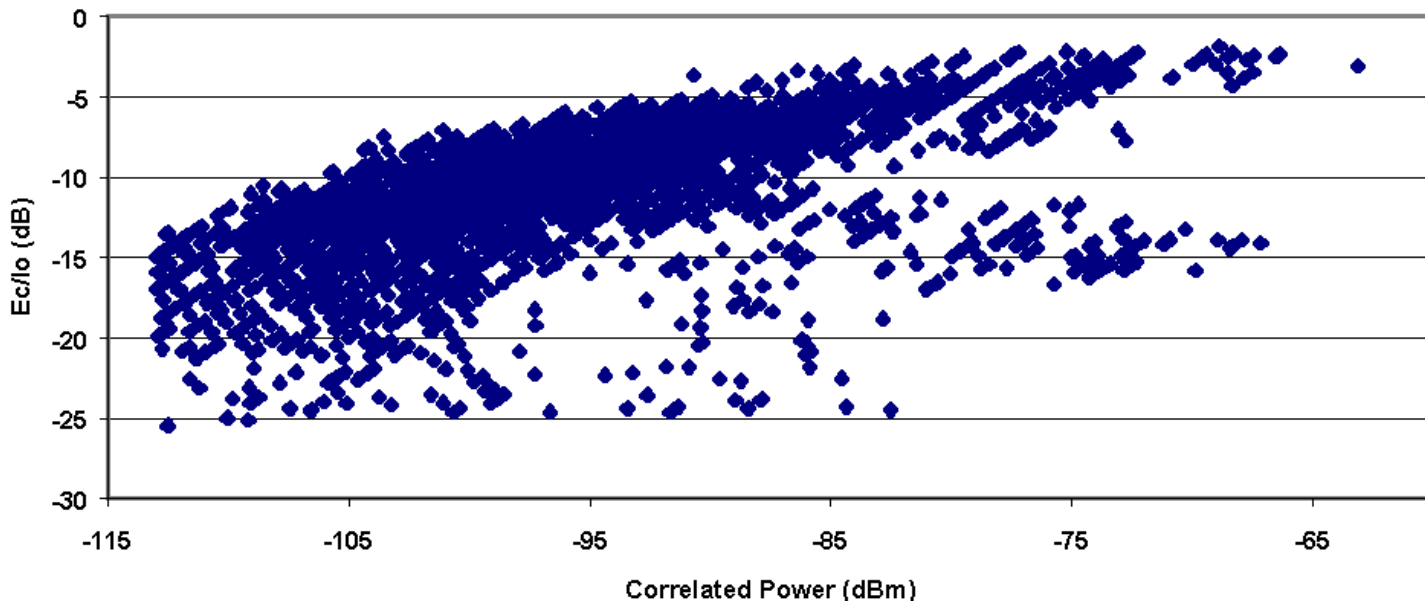


Figure 5: Scatter plot of Ec/lo vs. Correlated Power

Another indicator of PN pollution is given by close examination of the power delay profiles of a particular PN offset as provided by TECC's custom developed software. The Super Eagle uses GPS time and can calculate absolute time of arrival. Given the time delay associated with propagation, the absolute time a PN arrives at the receiver will vary with distance from the transmitter. However,

the arrival time will always occur after the absolute time associated with the PN offset. Consider Figure 6. A correlation peak of significant magnitude occurs at $t = -4.8$ ms and 0.81 ms with respect to absolute time. It is physically impossible that the -4.8 ms peak is from a base station assigned PN 396. A subscriber unit demodulating against PN 396 with a 20 chip Rake search window centered about the 0.81 ms peak would most likely “lock on” to the non-causal peak resulting in PN confusion and excessive frame error rate.

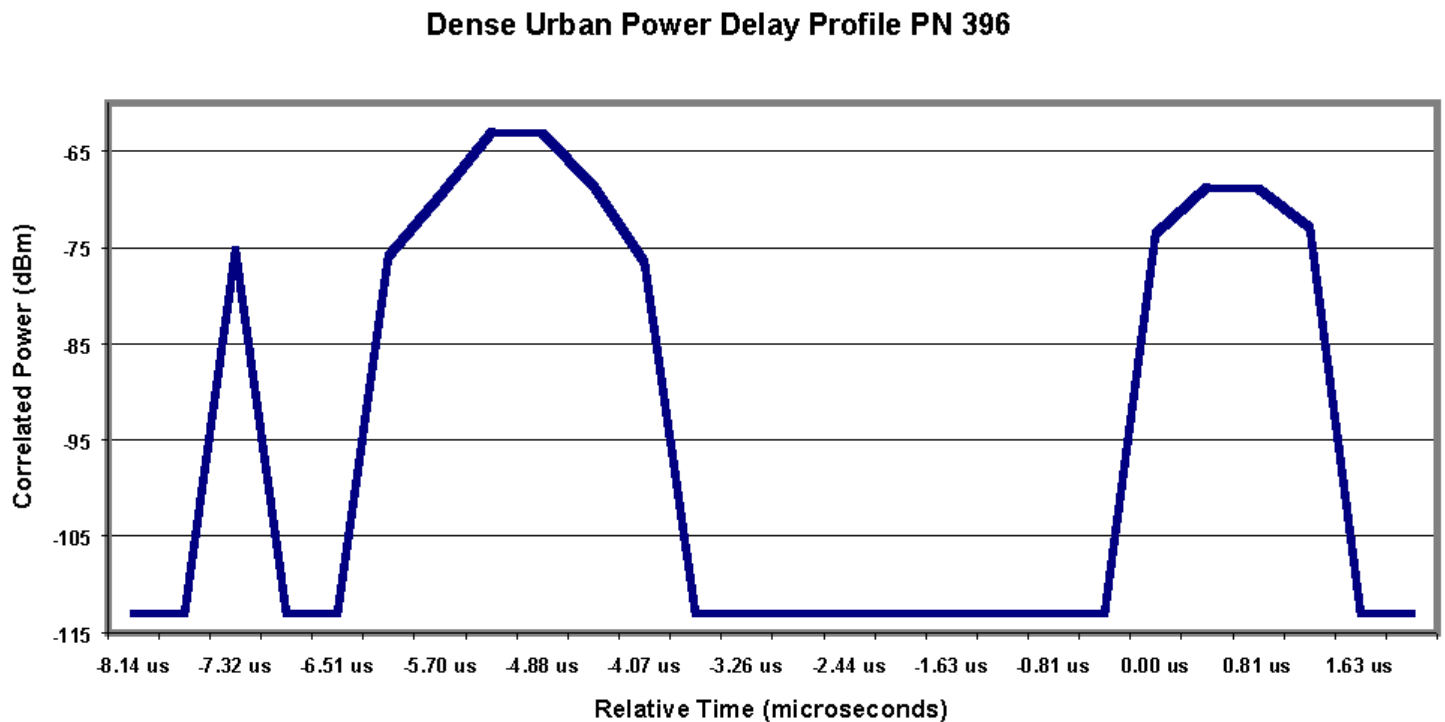


Figure 6: Post processed power delay profile showing PN pollution

5. Conclusions

Shown in this article are several examples of specific conditions and problems that are most easily detected using digitally modulated waveforms (both test and operating pilot signals), with a high speed scanning correlator receiver, and robust post processes tools. Our field experience and data shows that strong signal strength does not always correspond with strong levels of E_c/I_o . Multipath and interference from neighboring transmitters can effect signal strength and E_c/I_o differently. The equipment and software presented here can be used early in network design for site verification and measures E_c/I_o or signal strength. The Super Eagle pilot scanner and TECC software can be used to diagnose problems in actual CDMA networks that are best found with a high-speed pilot scanner that measures all possible pilots and has a time-base that is derived directly from GPS time.