Optimizing Performance and maximizing capacity in CDMA systems

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Several techniques can improve the performance and capacity of CDMA systems. RF engineers now realize that CDMA offers and opportunity to trade off capacity, coverage and call quality.

As PCS carriers operating code-division multiple-access (CDMA) systems finish deploying their phase-one "build-outs," they move to the optimization stage. Optimization is a critical stage that can significantly affect the performance and capacity of a CDMA system. Several techniques can be used to optimize CDMA system performance during this critical stage.

One of the easiest methods of "stealing" system capacity is to have too large of a soft hand-off zone. "Soft hand-off" is a state where the mobile is in communication with multiple base stations at the same time. "Softer" hand-off is when the mobile is in communication with multiple sectors of the same cell. A link is established with a target cell before the link with the currently serving cell is broken. CDMA gains several advantages by employing soft hand-off: fewer calls are dropped, less portable transmit power is required and less interference is experienced. However, as in many cases, too much of a good thing can hurt you. If the soft hand-off zone is too large, the system will have less capacity because two base stations are carrying the same call during soft hand-off, as shown in Figure 1, below. Soft hand-off is a compromise between system performance and system capacity. Greater soft hand-off usually improves performance, but it decreases capacity. The ideal amount of soft hand-off is about 25% to 40%. The need for minimized overlap between sectors is one of the reasons that CDMA operators are deploying 658 and 908 horizontal beamwidth antennas instead of the traditional 1058 and 1208 horizontal beamwidth antennas used in AMPS cellular. An operator must also ensure that the T_ADD, T_DROP and T_TDROP parameters are set correctly for optimum performance.

The RF engineer must be careful when making this critical decision regarding the use of narrower horizontal beamwidths. Although the trend has been toward narrower beamwidth antennas, with excellent results, there are exceptions. One operator deployed 808 horizontal beamwidth antennas on a few relatively high sites with disappointing results. In that application, there were significant "notches" in the coverage area between sectors. A general rule is that as tower heights increase and site radius widens, horizontal beamwidth will need to widen. Many operators are deploying 908 horizontal beamwidths for their CDMA sites, and some operators are using 658 horizontal beamwidths, particularly for dense urban areas.

Another important aspect of the horizontal pattern is the H-plane "roll-off." The more rapid the power roll-off beyond the 3dB beamwidth points, the higher the sectorization efficiency. If you overlay various antennas with the same 3dB beamwidths, you can observe that two or more antennas can have the same 3dB beamwidth, but some will roll off quicker beyond the 3dB points.

One last feature to look at in horizontal patterns for CDMA systems is high front-to-back ratios. The higher the front-to-back ratio, the less likely co-channel interference will be an issue off the back of the sector.

Another optimization method is to minimize areas suffering pilot pollution. Pilot signals act as beacons to notify potential users of the existence of a CDMA base station. Portables use the pilots for power strength comparison, which is essential for the process of a hand-off. The pilot signal is the strongest channel, containing 20% of the total radiated power in a CDMA signal. Each CDMA sector sends its own pilot signal, but they are all on the same frequency.

The portables in use today have a four-finger "rake" receiver. One finger is used to scan for pilots and the other three can "listen" for pilots. If a portable is in a location where numerous pilots are received with relatively equal signal strength, the result is pilot pollution.

Pilot pollution can cause dropped calls and decreased capacity. Drive testing in these areas will show a noticeable problem with frame-error rate. To avoid pilot pollution, operators can use antenna downtilt1, azimuth rotation and careful horizontal beamwidth selection. Some carriers in core urban areas have been using 338 sector antennas to minimize pilot pollution, as shown in Figure 2 at the right. Often, these antennas are used at sites located on bridges because signals propagate significantly greater distances over water.

Other methods of reducing pilot pollution used less extensively include lowering cell site heights, lowering cell site power and using repeaters. One method of battling pilot pollution is to ensure that one cell has a dominant pilot. This can be done by using a repeater to saturate a small area with one particular pilot. These are tools that the RF engineer can keep in his "tool box" for solving pilot pollution issues.

Some CDMA operators use continuously adjustable electrical downtilt antennas to minimize pilot pollution. When antennas are mechanically downtilted, the energy off to the sides of the antenna is not reduced on the horizon, and this energy can cause pilot pollution at nearby sites. Electrically downtilting the antennas reduces the energy on the horizon both in front of the antenna and on the sides. In situations where pilot pollution is caused from the side radiation of a nearby site, a continuously adjustable downtilt antenna can be adjusted while performing drive tests after each adjustment, to optimize the system for coverage and reduction of pilot pollution.

One often-ignored method of optimizing CDMA systems is tweaking the neighbor list. An operator needs to avoid a hand-off to a sector that may only temporarily provide good coverage, such as the high site shown in Figure 3 at the right. Tweaking the neighbor list allows the portable to be instructed as to which neighbors to search first for a good hand-off. If the portable hands off to the wrong sites, the call can be dropped, and capacity will be wasted as well. The neighbor list needs to be updated as new system sites are added. One final method of optimization is to ensure that your antenna system is minimizing the addition of noise and interference into your CDMA system. Noise and interference can significantly limit your system's capacity. Antenna intermodulation is one form of this noise and interference. Make sure that your system's antennas are designed robustly enough that their intermodulation (IM) performance does not decrease with time. The IM performance of designs using multiple cables and solder joints are susceptible to deterioration once the antennas are placed in an outdoor environment. Many antennas do not even meet their advertised IM specification before being placed on a site.

Antennas that use PC boards can also add a noticeable amount of noise to the system. For instance, if the PC board used in the antenna has a distributed loss of 2dB, this is the same (from a system noise standpoint) as adding a 2dB attenuator pad to the input of the antenna. This 2dB of loss will also improve the VSWR of the antenna, but for the wrong reasons. Remember, a 50V load can have a great match, but all the power is absorbed as heat. An operator needs to keep in mind that any losses in the antenna, such as lossy PC board material, will negatively affect the receiver sensitivity.

Operators also need to understand the compromises and potential negative impact of using polarization diversity in a system.

There are many methods for improving the performance and capacity of CDMA systems. RF engineers realize that CDMA offers us an opportunity to trade off capacity, coverage and call quality.

Complaints about high reflected power, high VSWR or poor match all mean the same thing. The antenna does not appear to be absorbing as much power from the transmitter as it should. It must be determined whether the installation or the product is the cause. Answers to the following technical questions can help determine if the product qualifies as defective per the manufacturer's warranty. (This presumes all connections are clean, dry and tight and that all test equipment is in good condition and properly calibrated.)

1. What is the VSWR you measured? Check to see if it is a higher number than the catalog value for this product. For example, many antennas have a match of 1.5:1 or 1.6:1 across a specified bandwidth. Performance at a VSWR greater than 2.0:1 may be unsatisfactory. Some technicians will refer to match as "return loss," in which case rates of 14dB or 12dB apply. Performance at a return loss of less than 9dB may be unsatisfactory. 2. What test equipment did you use?

Check to see that the equipment has been properly calibrated and that any connector adapters are of good quality. A poorly matched adapter will invalidate the results.

cWattmeter/power meter - These devices are inexpensive, and therefore, more common, but they can be inaccurate, particularly if more than one RF carrier signal is present. Technicians who use wattmeters and power meters will eagerly tell you how many watts of power is reflected back to the transmitter, but often they do not know the actual mismatch. The forward power measurement is required to calculate the VSWR or return loss number. This can be tricky because some transmitters have an output stage protection circuit that reduces power under highly reflective conditions.

cNetwork analyzer/spectrum analyzer with tracking generator - These devices do not rely on the site's transmitter as a signal source. They can produce more accurate and meaningful results, but they do not subject the antenna to full power, when arcing or flashover would occur.

cTime domain reflectometer - Occasionally, a technician will use a TDR. This is not an industry-recognized instrument for antenna testing, and many manufacturers will not respond to these measurements because they do not use RF and do not measure beyond bandlimiting devices.1

3. Did you perform the measurement directly at the antenna's connector? The technician may have chosen not to perform this test because it requires climbing the tower. This procedure should be done to eliminate jumper cable or downlead cable factors. The cables could be defective and causing the problem. They could also be fine, but they could be absorbing the reflection that masks the problem.

4. What is your operational frequency? Check to see if the antenna was ordered for the correct frequency. The manufacturer may have mismarked the antenna or carton. Several methods can determine an antenna's frequency. If the technician has swept the response of the antenna, he will know the frequency of the best match. That should be its designed frequency. The technician can also measure the physical length and compare it to a cut chart. This is a crude method. If the antenna is relatively new and the model number is known, the factory may still have the production test data sheet that will identify its frequency by serial number.

5. Did you measure the antenna erect, free and clear of metal objects?

Side mounting too close to the tower can detune an antenna. The required spacing distance between the antenna and any other metal object decreases as the operational frequency increases. Some good numbers per our factory test procedure for omnidirectional antennas are from 100 feet at 30MHz to five feet at 900MHz.

6. What is the dc continuity, as measured with an ohmmeter? Some antennas have direct ground lightning protection. These normally measure as a dc short between the connector's inner and outer conductor but will be the proper 50V impedance at RF. See "lightning notes" in catalog specifications to determine if the antenna will measure as an open or a short.

7. Did you have the opportunity to substitute an identical antenna? If the second antenna measures OK under the same mounting conditions, the technician's first antenna is probably defective. If the second one yields the same bad result, the problem is unlikely to be the antenna. Perhaps the transmitter is not operating on the expected frequency.

8. When was the antenna installed? It could either be new and defective or one that had performed nominally for some time before failing. It is a good practice for technicians to test products on receipt before transporting them to the job site. Manufacturers' warranties cover only manufacturing defects, not damage from an improper installation. An example would be mounting a standard antenna upside-down. This would put the drain hole at the top, where it could collect water and cause the product to fail over time. Factory options given to an inverted antenna include reconfiguring both the drain hole location and any electrical beam tilt.

9. Are the antenna drain holes open? They are placed at the bottom of the antenna for draining internal moisture. Periodic inspection of these openings is the responsibility of the owner. They must remain clear of debris to preclude corrosion from internal condensation. Such damage can drastically affect performance, and it is not covered by warranty.

10. Is the antenna intermittent? It is a good idea to shake the antenna during the above tests to ensure there are no mechanical intermittents. Poor connections may lead to RF intermodulation products. Water entering the antenna may lead to electrical intermittents that subside when the antenna dries out.

Match is only one indicator of antenna quality. VSWR tells us how well the product's impedance matches to (absorbs) a transmitters signal, and it is easy to measure in the field. Unfortunately, VSWR does not reveal an antenna's efficiency (how well it radiates the signal). This measurement (an antenna's radiation pattern) is more difficult to perform in the field. We may presume that match bandwidth and pattern bandwidth are equal, but this is not always true. For example, operating an end-fed antenna below its design frequency will result in an electrically downtilted vertical pattern. Usually, substitution with an identical unit of known quality is the method of choice when a defective product is suspected.

The typical VSWR for a good antenna is 1.5:1. Although some site engineers may specify a minimum acceptable value of 1.3:1, there is only a miniscule improvement. For example, at a 1.5:1 ratio, 4.0% of the power is reflected back, creating a 0.18dB loss. At a 1.3:1 ratio, 1.7% is reflected, resulting in 0.07dB loss. The performance improvement is only 0.11dB.

It is a good idea to document performance upon installation. This is usually done by choosing a remote site and measuring the signal level received from the transmitter. Periodic measurements at that same location will reveal the amount of any degradation so that corrective action may be taken.