Numerical Study of Antenna Parameters for Sectorized W-CDMA Networks

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Given the limit on spectrum resources, efficient optimization techniques are needed for realizing cost efficient ways to maximize the capacity in a W-CDMA network. The capacity is essentially interference limited by the overall interference level in the coverage area of each site. A computer simulation for investigating the system capacity was performed that modeled the radio channel in an urban environment. The simulator included CDMA characteristics such as power control and different parameter setting in the hand over algorithm. Antenna characteristics such as sector orientation, number of sectors per site, horizontal beamwidth and front-to-back ratio were studied. The influence of the radio environment, giving rise to different orthogonality factors, were also studied.

The Signal-to-Interference Ratio typically limits the probability of having service in a dense cell site. The roll off of service probability for voice traffic is quite quick from 160 to 180 users per cell site in a typical three sector configuration compared to about 90 users for omni site configurations. The error bars in the following figures annotate -one standard deviation about the mean value obtained from the numerical simulations.

With the simulation conditions, the practical number of users is between 170 and 175. Depending on the antenna characteristics, the number of actual users that can talk on a given sector face will change.

The typical shape for cell site footprints is a hexagonal shape. For such a shape, the typical number of sectors per cell is one, three or six. When using three or six sectors, there are two standard orientations.

To further increase the capacity at each cell site without increasing the number of W-CDMA carriers, a common practice is to increase the number of sector faces at the desired cell sites. Figure 1 illustrates a common six-sector configuration.

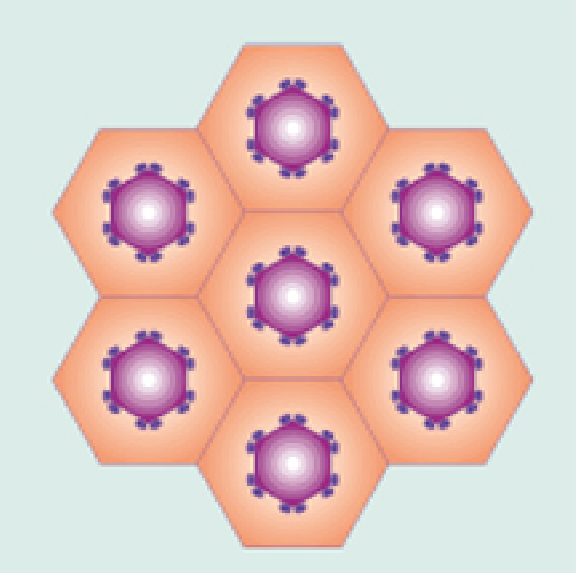

Figure 1. Typical six sector cell site configuration.

Figures 2 and 3 show the three different site configurations the anticipated maximum number of voice users in a typical urban network, respectively.

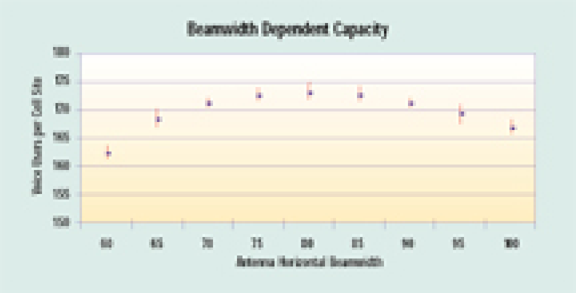

Figure 2. Capacity predictions for a typical three sector cell site configuration rotated by 30 degrees.

Figure 3 shows that the optimal beamwidth for the configurations demonstrated is 65, 80 and 40 degrees respectively.

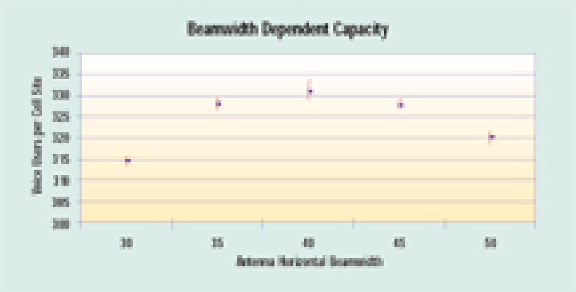

Figure 3. Capacity predictions for a typical six sector cell site configuration.

As demonstrated, the rotational orientation of the sites and the number of sectors per site require different beamwidth antennas for optimal capacity performance. The choice of the proper antenna beamwidth is a compromise between the interference in the network by having antennas with too broad a beamwidth and the coverage holes induced by having antennas with too narrow a beamwidth. For all the capacity predictions, the overhead for the pilot was assumed to be 5% and the number of sectors involved in a soft handoff was limited to three.

The capacity of the W-CDMA network is also limited to the amount self induced interference by the mobiles using the same sector face. This self-induced interference is the disruption of the orthogonality of the codes by the multi-path in the wireless network. Although the fingers in the rake receiver provide some additional diversity in a high multipath environment, the multipath is detrimental to the orthogonality of the W-CDMA channel. For the previous results, an orthogonality factor of 0.4 is used. Figures 4 and 5 shows a study of maximum orthogonality and no orthogonality in relation to antenna beamwidth.

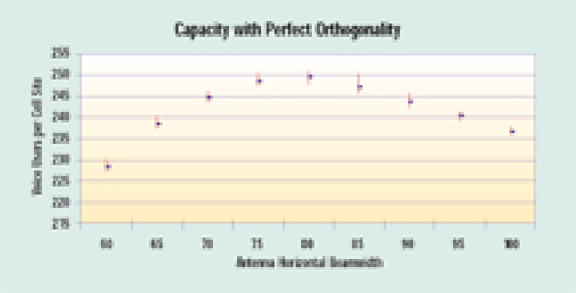

Figure 4. Capacity predictions for a typical three sector cell site configuration rotated by 30 degrees with a maximum level of orthogonality.

Here, the optimal beamwidth of the antenna is quite invariant to the level of orthogonality in the network. Over the complete range of orthogonality, the optimal beamwidth varies from 75 to 80 degrees.

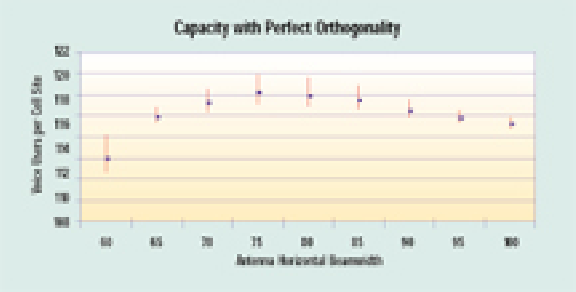

Figure 5. Capacity predictions for a typical three sector cell site configuration rotated by 30 degrees with no measurable amount of orthogonality.

Figures 4 and 5 show that the orthogonality of the W-CDMA channel significantly impacts the network capacity. Another contributor to the degradation of the W-CDMA channel is the radiation from the antennas in the backward direction. All of the results presented are for antennas with a front-to-side ratio of 30 dB. If the radiation from the base station antenna is increased in the backward direction in the form of a single back lobe, the degradation of the capacity can be studied.

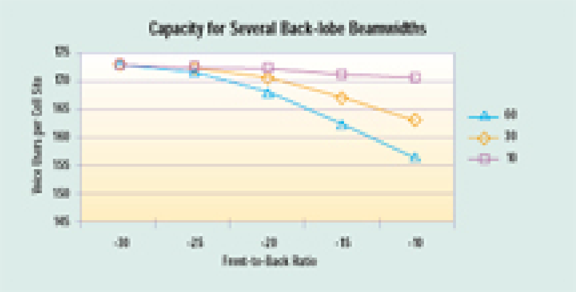

Figure 6. Capacity predictions for a typical three sector cell site configuration rotated by 30 degrees. The different lines are for the back-lobe beamwidths 60, 30 and 10 degrees.

Figure 6 shows that as the total energy in the backward directed lobe is increased by increasing the beamwidth of the back-lobe or decreasing its front-to-back ratio, the capacity of the W-CDMA network diminishes. The capacity of the W-CDMA network can be optimized by choosing antennas that have the proper beamwidth for the given environment and cell site configuration.

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