Paper

Optimal site and antenna location for UMTS – output results of 3G network simulation software

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Abstract — The paper presents output results of 3G network simulation software in the area of optimal site location as well as finding optimal values of antenna tilt. The loss of capacity is shown for a wide range of tilts and different antenna directions. Nonuniform distribution of base stations has been also included in the simulation scenarios influencing system performance. All of the described parameters are especially significant to CDMA systems network planning.

Keywords — UMTS, 3G, CDMA, antenna tilt, site location.

1. Introduction

Soft-like behavior of 3G systems based on coded multiple access technique requires extensive analysis and optimisation related to WCDMA network planning. It becomes increasingly complex and sophisticated. An intuitive approach to solving CDMA related problems often leads to results inconsistent with reality. In TDMA/FDMA systems each of the planning stages can be treated independently, whilst the specificity of WCDMA radio interface causes all of the process elements to be interdependent.

The Institute of Telecommunications and Acoustics of the Wrocław University of Technology, Poland is conducting intensive research pertaining to CDMA cellular network modeling with special attention to the UMTS system.

Finding parameter values required to achieve a given network capacity is the main purpose of these analysis. The parameters modifiable by the operator include site locations, antenna directions and down-tilt values. Having appropriate control over these factors allows for the system capacity to be increased without any additional financial investments in new equipment.

2. Basic capacity calculations

The main term used to define the preliminary rough estimate of the system capacity is *pole capacity* [4, 5]. It states the maximum theoretical number of channels available in an ideal system with unlimited power resources. This number of channels for a multicell system and both link directions is determined through the following relation:

$$n = \frac{R_c}{R_b \cdot \frac{E_b}{N_0+I_0} \cdot (O_f + F)} + 1, \qquad (1)$$

where: n – the number of subscribers in a cell, R_c – the chip rate, R_b – the service bit rate, $E_b/(N_0+I_0)$ – the required energy per bit to noise and interference power spectral density at the receiver input, O_f – the orthogonality factor, F – the ratio between received intercell and intracell power. For a downlink O_f varies from 0.05 to 0.5 depending on the propagation environment. For an uplink it is assumed at $O_f = 1$. Considering that the F downlink value can vary for various distances between MS and BS, an averaged value should be used.

Unfortunately, the *pole equation* can only be used to roughly estimate the system capacity. Because the intercell and intracell interference are related to each other it is very difficult in practice to determine the F value using analytical methods even for an uniform distribution of subscribers at the given area.

The *pole equation* does not provide any information about the power emitted by the base stations and terminals. It is extremely important especially in the cases of nonuniform distribution of subscribers or base stations within a given area. The predicted power characteristics of network elements are the most important factors in the network planning process. This allows for example for a conclusion about the optimal antenna location.

The pole capacity in the same terms as (1) does not depend on the thermal noise and existence of control channels in the system, whilst the actual system capacity depends on these parameters.

A proper model of CDMA networks should include all or "almost all" of the intrasystem interference. More detailed description can be found in [3]. The main characteristic for a downlink is the total base station TX power as a function of the system load and active subscriber distance to the base station. For an uplink the system capacity is limited by an interference level measured at the base station. All results presented in the paper pertain to a system with the parameters shown in Table 1.

A non-heterogeneous propagation environment impacts the simulation results. The shadowing effect causes degradation of the system capacity. In order to simplify the calculations it is a common practice to assume a model, where the path loss is assumed as a sum of attenuation values resulting from the close to 4th power rule and of a random variable with a log-normal distribution. The standard deviation of this variable for an urban area can be stated between 4 to 12 dB. It also seems to be important to take into account the correlation factors between different MS locations.

Table 1
Assumed parameters values

Parameter	Value
Carrier frequency	2 GHz
User bit-rate (voice)	12.2 kbit/s
Chip rate	3.84 Mchip/s
Orthogonality factor	DL: 0.4, UL: 1
Voice activity factor	100%
Required $E_b/(N_0+I_0)$	DL: 7.9 dB, UL: 6.1 dB
Maximum TX power per TCH channel	DL: 30 dBm, UL: 24 dBm
Receiver noise figure	NodeB – 5 dB UE – 9 dB
NodeB maximum TX power	DL – 43 dBm
TX power in the CCH channels	DL – 33 dBm
Propagation model	Walfish-Ikegami based
Antenna gain	NodeB – 15 dB UE – 0 dB
Cells radius	R = 500 m, 3 km
Number of cells in the model	19,37
No SHO, ideal power control, uniform subscriber distribution	

3. Sector antenna directions in hexagonal layout

CDMA is a single frequency network (SFN). As we already know its capacity is limited by interference levels. Placing the base stations according to a hexagonal grid we can obtain two totally different borderline cases when it comes to interference, depending on the directions of the sector antennas. Both of these are shown in Fig. 1.

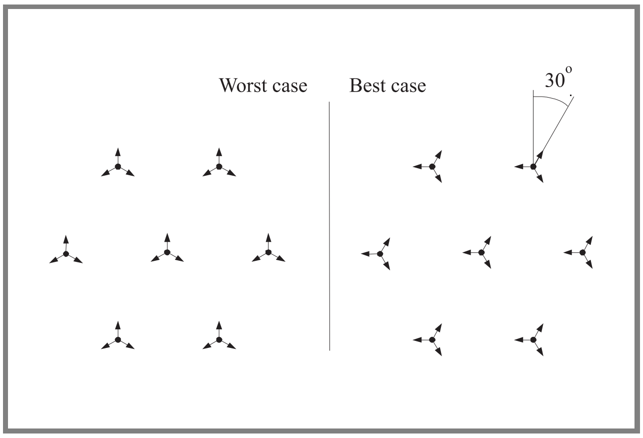

Fig. 1. Best and worst case of antenna directions for CDMA systems.

Figure 2 presents the TCH channel TX power characteristic as a function of the network load. An improper direction of sector antennas can cause a capacity degradation exceeding even 20% and requires an increase of base station TX power from 3 to 6 dB (assuming a uniform distribution of terminals within the test area). The decrease pertains not only to the capacity depending on the finite maximum power of the transmitter (in this case +41 dBm), but also to the *pole capacity*. The graphs shown in Fig. 2 represent average values.

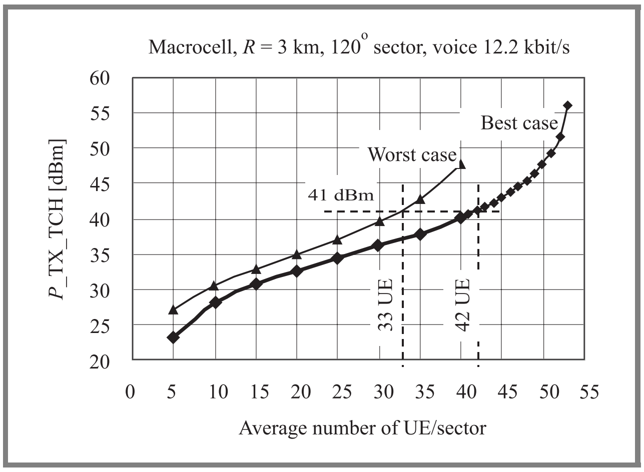

Fig. 2. Base station TX power for best and worst cases.

4. Base station antenna down-tilt

Base station antenna down-tilt is a common practice used in cellular networks. In CDMA networks it becomes especially important as the system performance is limited by interference coming from other cells.
The simulations are based on the characteristics of a Cellwave APX206513-T0 antenna designed for the 1900–2170 MHz frequency band. Its gain is about 15 dB and it gives a beam width of 65° (3 dB). Figure 3 presents the vertical characteristic. This is a typical antenna, which can be used in tri-sector UMTS base stations.
Figure 4 shows the total combined TX power of TCH channels as a function of the antenna down-tilt at three different load levels. The graphs clearly show, that significantly loaded (50 UE/sector) system with high antenna down-tilt (as compared to tilt = 0) have greatly reduced TX power. More detailed characteristics have been shown in Fig. 5.
Figure 5 presents the total combined TX power of TCH channels as a function of the load level for different down-tilts. At a first glance we see an interesting property. Having tilts lower then 5° the total combined TX power in the TCH channels decreases. However, with tilts exceeding 5° this power rises. Thus, the actual capacity of the system decreases because of the finite power limitation of the transmitter. At the same time, the more we tilt the antenna the higher the *pole capacity*. To sum up, with a given

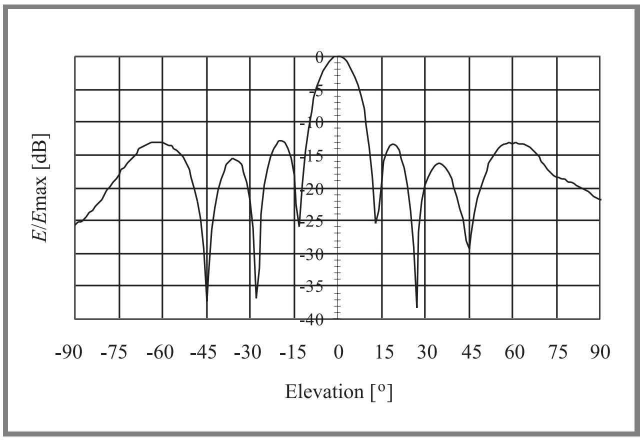

Fig. 3. Vertical characteristic of base station antenna.

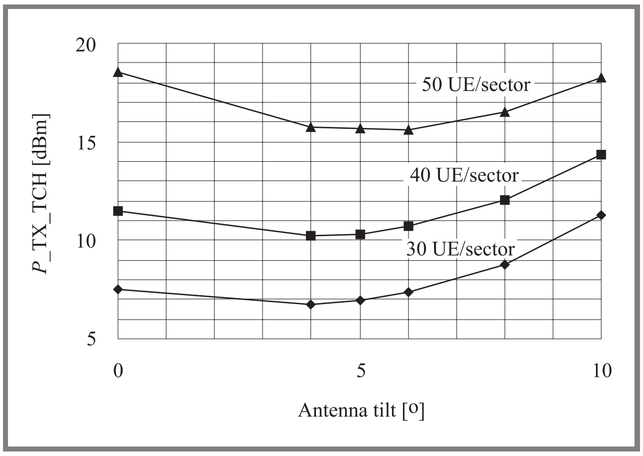

Fig. 4. Base station TX power versus antenna down-tilt.

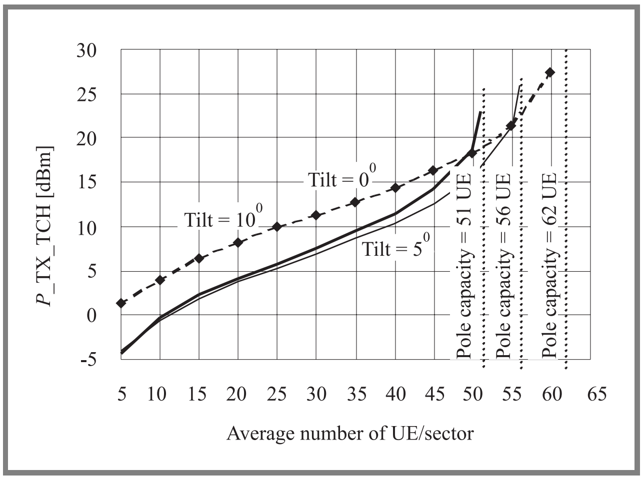

Fig. 5. Base station TX power curves for specified tilt values.

cell load when the antenna is tilted the total combined TX power lowers to a certain borderline value. With further tilting the power level rapidly rises depending on the given antennas characteristic, and the actual capacity decreases. At the same time the theoretical capacity actually rises. Considering the above, if the load is high and the transmitter has appropriate reserve TX power, it is possible to increase the number of available channels by tilting the antenna or choosing an antenna with an appropriate characteristic. The above seems obvious when we take into account the vertical characteristic of an antenna (Fig. 3). The down-tilt causes the antenna directional gain to drop in a direction parallel to the ground surface (at 10 dB for a down-tilt of 10°), thus lowering the level of interference onto the adjacent cells. This in term lowers the value of the F coefficient in formula (1) and thus the pole capacity rises.

5. Irregular base station distribution

One of the environmental parameters, which can be varied by the operator, is base station location. This parameter is especially significant for systems using coded multiple access, as these systems can handle loads of variable and irregular nature. Figure 6 presents capacity loss for base station location irregularity varying from 0% to 30% of the cell radius. Calculations were done for an uplink and a downlink.

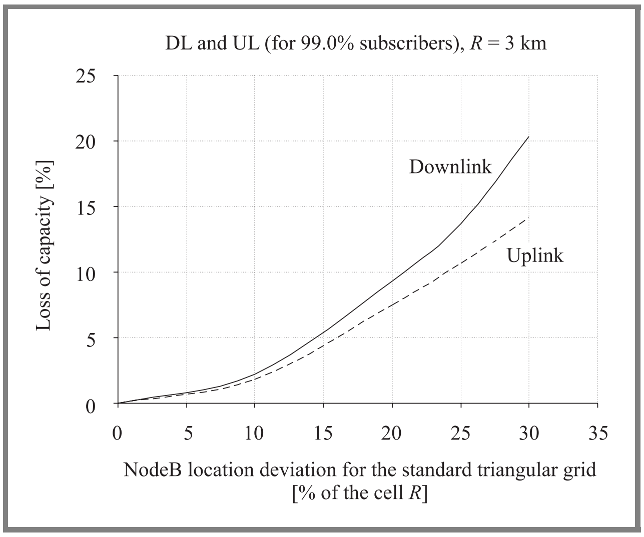

Fig. 6. Cell capacity loss for both link directions as a function of NodeB location deviation.

For a deviation of NodeB location equal to 30% of the cell radius, the number of available channels will be about 14% less as compared to an even base station distribution for an uplink and 20% for a downlink.

6. Summary

The paper presents an influence of site location and antenna tilts onto the operation of UMTS systems. The down-tilt of base station antennas is especially significant for CDMA systems. In order to obtain the best results it is necessary to have a detailed antenna characteristic for both the horizontal and vertical planes. Improper base station location and/or improper antenna direction can greatly reduce the system capacity. On the other hand, it should also be noted that the UMTS system has cells of various size and hierarchy (macrocells, microcells and picocells), which will allow to significantly improve the system performance in reference to irregular base station locations. Also, the results pertain to a network using a singular bandwidth of 5 MHz.

The conclusions arising from the presented calculations are especially important to engineers involved directly in network planning. It is obvious that in urban areas it is not possible to freely place base stations at any and thus optimal locations. Considering the above, the deviation of base station antenna location in reference to the ideal triangular grid is very important during the network planning process. This data will also allow for easier network scalability under varying and irregularly distributed loads at a given area, especially for single frequency networks as the case of UMTS.

The cellular operators who received the UMTS license are nowadays faced with the fact that WCDMA interface cellular network planning is much more complicated then GSM. Just a few years back it was thought that CDMA type networks will require almost no planning because the coded access method, which dynamically adjusts the system resources within each cell based on the traffic requirement, will allow the network to "plan itself". After detailed analysis of the problem it is evident that the amount of significant parameters influencing the capacity is much larger than in TDMA/FDMA systems. Additionally, minor changes of the system or environmental parameters can influence the parameters of the entire system.

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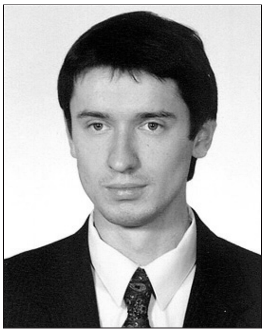

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