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INFLUENCE OF ELECTRICAL BEAMTILT AND ANTENNA BEAMWIDTHS ON DOWNLINK CAPACITY IN WCDMA: SIMULATIONS AND REALIZATION

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Abstract— **Optimizing the beamtilt and a proper choice of azimuth and elevation beamwidths are shown to be key factors in improving system downlink capacity in reuse-one mobile telephony systems such as WCDMA.**

Several antennas with remotely controlled electrical beamtilt with 90° azimuth beamwidth are currently in production. Measurements show radiation characteristics with excellent front-to-back ratio, sidelobe suppression and low cross-polarization.

I. INTRODUCTION

Beam-tilt, either mechanical or electrical or a combination thereof, is frequently used in 2nd generation mobile telephony system installations such as GSM. The purposes are in principal twofold; one is to adopt the direction of the antenna beam to the sector terrain to improve coverage; the other is to reduce transmission into other cells thereby reducing interference spread and as a consequence increasing system capacity.

In this paper we show that beamtilt is an efficient way of improving system capacity also in reuse one systems, such as WCDMA, although there are fundamental differences in the interference situations between GSM and WCDMA. In downlink, for example, the desired user and a user being interfered can be located fairly close to each other, e.g. at each side of the cell border.

The outline of this paper, which is focused entirely on downlink, is as follows. In section II the system simulator used for performance evaluation is presented. In section III simulation results for the system performances downlink capacity and downlink power consumption are given. In section IV realizations of antennas with 90° azimuth beamwidth and remotely controlled electrical beamtilt are presented, together with measured radiation patterns. Finally, in section V a short discussion and a summary of the results are given.

II. SYSTEM SIMULATOR

The system simulator used here comprises an, in principal, infinite number of sites. Some of the most important characteristics are:

- UEs uniformly distributed over the system;
- all traffic modeled as speech;
- identical antennas in all cells;
- identical beamtilt applied to all cells;
- handover margin –3dB with max size of active set = 3;
- path loss exponent 3.5;
- angular spread in elevation, $\sigma = 0.6°$;
- shadow fading not included;
- common channels not modeled.

The antenna patterns used in this analysis are of outmost importance. Six different patterns are used in the study, see Table 1. Figure 1 shows azimuth cuts and Figure 2 elevation cuts of the antenna patterns.

Two types of systems are studied. One is the so-called Ericsson plan that is characterized by each beam pointing directly to the closest site. The other is the Bell plan in which beams from three neighboring sites are directed towards the symmetry point in between these sites. An example of an Ericsson cell plan (cell shape depends on pattern parameters) and the Bell cell plan are shown in Figure 3. The 65° and 90° patterns are evaluated in the Ericsson cell plan while the 90° and 120° patterns are evaluated in the Bell cell plan.

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Table 1. Antenna pattern data

Name	Gain	Azimuth		Elevation	
	[dBi]	HPBW	SLL [dB]	HPBW	SLL [dB]
65 Full	20	65°	-15	2.6°	-15
65 Half	17	65°	-15	5.5°	-15
90 Full	20	90°	-15	1.9°	-15
90 Half	17	90°	-15	4.0°	-15
120 Full	20	120°	-15	1.4°	-15
120Half	17	120°	-15	3.0°	-15

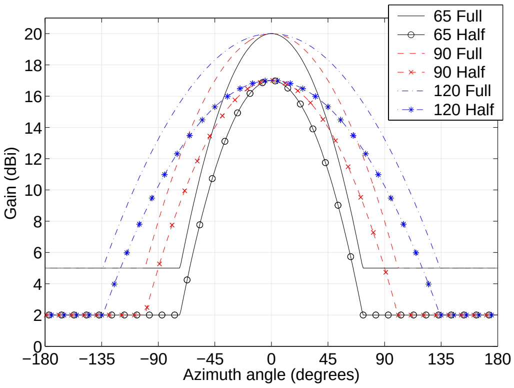

Figure 1. Antenna patterns, azimuth cut.

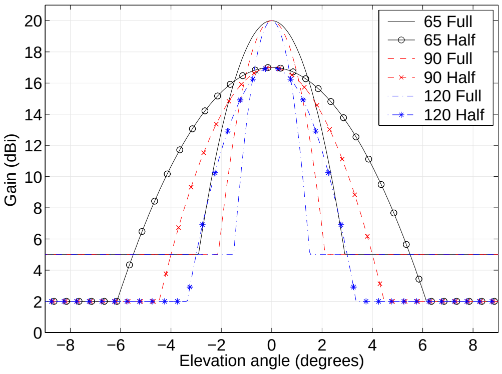

Figure 2. Antenna patterns, elevation cut. The beamtilt angle set to 0°.

III. SIMULATION RESULTS

Two different types of performance are presented. The first performance is the "pole capacity" defined as the maximum capacity possible while still fulfilling the desired quality for each user. This capacity is found by loading the system until no solutions to the power equation can be found, i.e. the SINR quality requirements is no longer fulfilled. At pole capacity the required power asymptotically approaches infinity.

The second performance presented is the total power consumption in downlink when the system load is a fraction the pole capacity.

The geometries used in the simulations are given in Table 2.

Table 2. Simulation geometries

	Fullsize	Halfsize
Antenna height	30 m	30 m
Site-to-site distance	2000 m	800 m

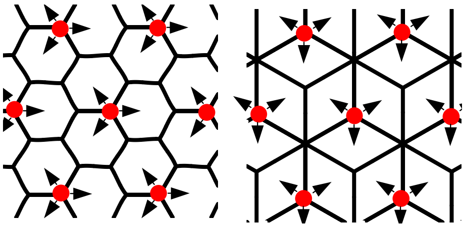

Figure 3. Ericsson cell plan (left) and Bell cell plan (right). Base stations are located at the dots and the arrows indicate the antenna directions.

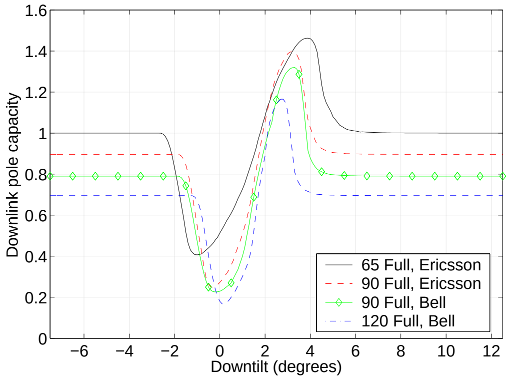

Figure 4. Pole capacity in downlink as a function of tilt angle for full-size antennas.

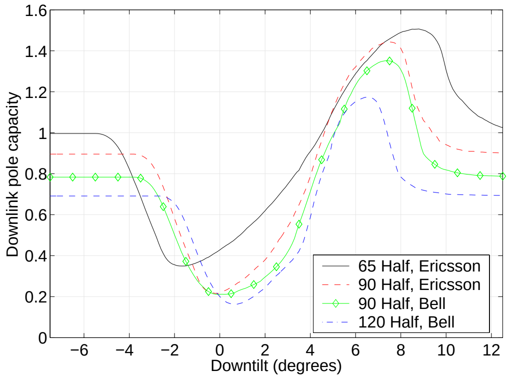

Figure 5. Pole capacity in downlink as a function of tilt angle for half-size antennas.

A. Pole capacity

Pole capacity, the maximal theoretical load, is shown in Figure 4 and Figure 5 for full-size and half-size antennas, respectively.

One observation is that the wider the elevation beamwidth, the less variation in capacity over tilt angles.

A second observation is that the elevation and azimuth beamwidths must be selected carefully to reduce variations in illumination of the cell (i.e. path gain), since these variations are of outmost importance for the pole capacity. Note that all antennas within each category, full-size and half-size, have the same gain, and the elevation beamwidts are chosen to ensure that.

A third observation is that correctly optimized beamtilt significantly improves pole capacity compared to zero beamtilt.

B. *Power consumption in downlink*

The second type of performance is the power consumption. In this case we present the total power required per cell in downlink. The required power is shown as a function of tilt angle at two different loads. The upper plot in Figure 6 shows total power consumption when the load is 70% of the pole capacity at large tilt angles for the “65 Full” antenna. The lower plot shows the same thing but for a load of 85%. Similar data for half-size antennas are shown in Figure 7.

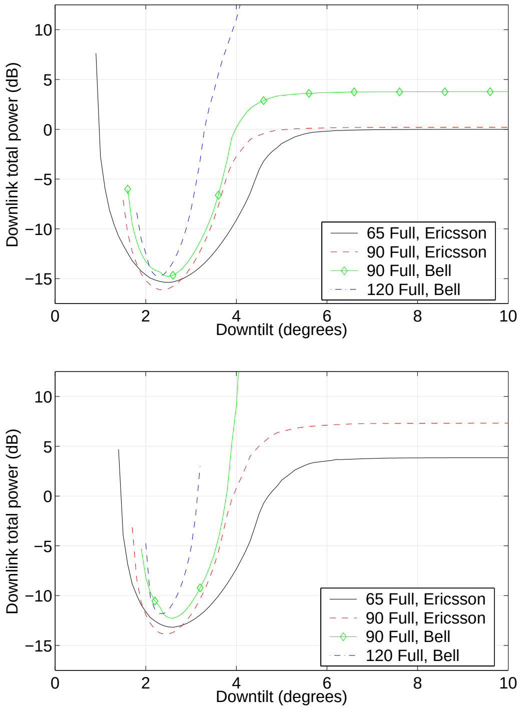

Figure 6. Total downlink power as a function of tilt angle and load. The load is 70% (top) and 85% (bottom) of pole capacity for “65Full” at large tilt angles.

The plots show, again, that a narrow elevation beamwidth is more sensitive to a correct setting of the tilt angle than a wider beam. As for the pole capacity, beamtilt significantly improves power consumption performance.

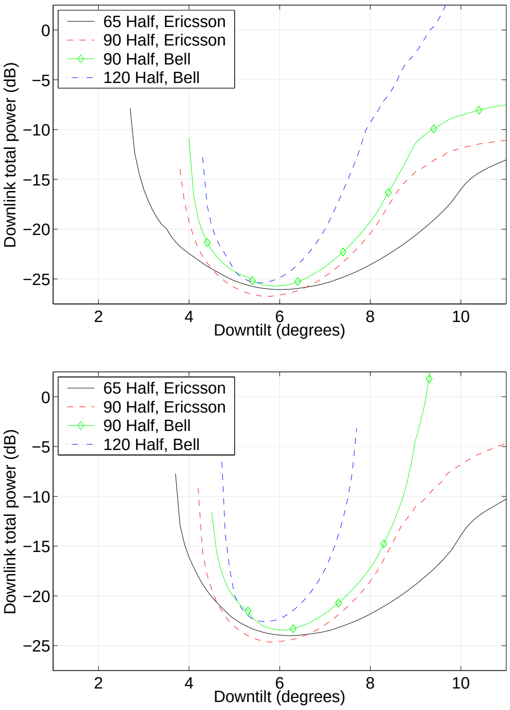

Figure 7. Total downlink power as a function of tilt angle and load. The load is 70% (top) and 85% (bottom) of pole capacity for “65Half” at large tilt angles.

IV. REALIZATION

A. *Antennas*

Ericsson today manufactures 4 types of 90°, vertically polarized antennas for use in 3-sector WCDMA systems; full-size (20dBi) or half-size (17dBi), and 1 or 2 beams in each antenna. The two-beam antennas are essentially two antennas within one radome, with the beams pointing 120° apart in azimuth.

The range in which it is possible to vary the beamtilt angle is dependent on the product, but is typically in the range of 0°-10°.

The beamtilt is accomplished by changing the phase to each subarray, which consist of 4 or 5 elements in height. This design is a trade-off between system complexity and antenna performance.

The amplitude and phase of the subarray excitations have been optimized to achieve a sidelobe level of <-15dB up to 15° above the main beam, for suppression of interference to/from neighboring cells, and to remove the first null below the main beam, for good coverage close to the antenna.

The antenna patterns exhibit a front-to-back power ratio of >21dB, low sidelobes in elevation and low cross-polarization, see Figure 8-Figure 11.

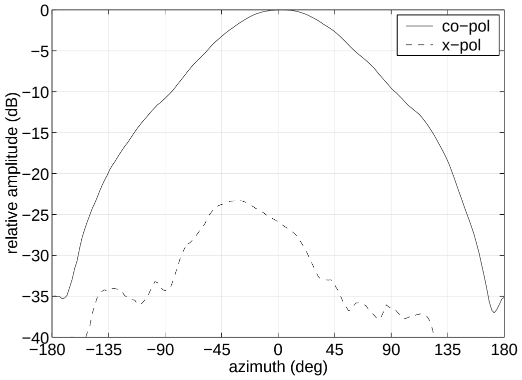

Figure 8. Azimuth pattern at 2045MHz for a full-size 90° antenna.

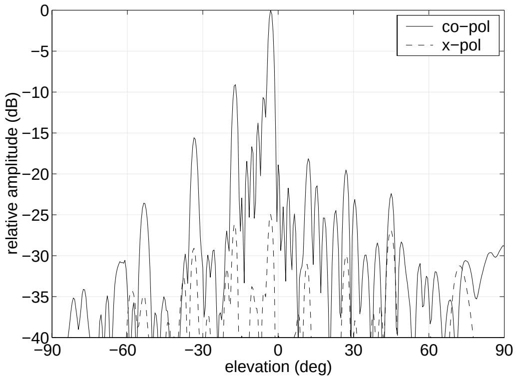

Figure 9. Elevation pattern at 2045Mhz and 3° tilt for a full-size 90° antenna.

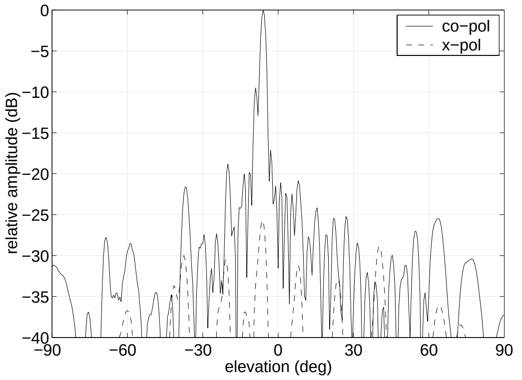

Figure 10. Elevation pattern at 2045Mhz and 6° tilt for a full-size 90° antenna.

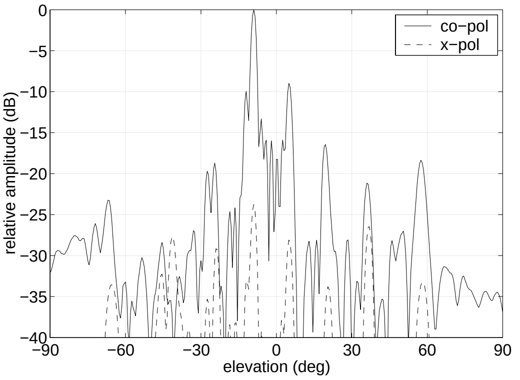

Figure 11. Elevation pattern at 2045Mhz and 9° tilt for a full-size 90° antenna.

B. Control System

The optimal tilt angle for a certain type of antenna is site- and load-dependent. For efficient use of the radio access network, the antenna beam tilt is possible to control from an operation center, so called remote electrical tilt (RET).

The purpose of the control system is to perform the antenna beam tilt setting, as requested from the operation center, and to supervise and relay any alarms back to the operation center. The beam tilt is set per beam independently for optimal system performance.

The tilt angle of each antenna can also be set locally by connecting a portable PC to the control system, or manually on site without using the control system.

V. CONCLUSIONS

Electrical beamtilt, azimuth and elevation beamwidths are shown to be key factors for improving downlink performance in a reuse-one mobile telephony system. To achieve the potential gains, which depends on antenna parameters as well as cell characteristics, the setting of the beamtilt angle needs to be optimized.

4 types of 90° antennas with remotely controlled electrical downtilt and 17 or 20dBi gain have been developed for use in 3-sector WCDMA networks. The measured radiation patterns show excellent performance.