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Simple Smart Antenna Models For System Level Simulation of Advanced Handover and Channel Allocation Protocols

Jan Steuer, Tilmann Giese, Klaus Jobmann

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University of Hanover,
Institute for Communications (IANT)
Appelstr. 9a
D-30167 Hannover / Germany

Tel. ++49-511-762-2837
Fax ++49-511-762-3030

E-mail steuer@ant.uni-hannover.de

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Jan Steuer, Tilmann Giese, Klaus Jobmann

University of Hanover
Institute for Communications
steuer@ant.uni-hannover.de

Abstract

This paper proposes simplified antenna models and a approximation for a position estimation algorithm for a system level simulation of advanced handover protocols with smart antennas. This models have been implemented in our simulation tool MOSIT that is based on the Specification and Description Language SDL (ITU Z.100). The application to be reported on is a simulation tool for the examination of a new approach for an advanced handover protocol that uses the estimated direction of arrival of adaptive antennas in combination with other mobile movement prediction methods to reserve capacity in the next predicted radio cell in order to reduce blocking rates and signalling.

1 Introduction

For system level simulations three basic concepts are often used as the computation of a complete link and system level simulation is still too complex for state of the art computers.

One concept bases one the idea to simulate at first the network situation. In second step the situation for a single link is examined with a link level simulation for a short snapshot [10]. A second idea uses pre-calculated link level values for a standard scenario. This model is problematic because the algorithm for channel allocation, handover and - in dependence on them - the power control algorithm change the situation on the communication link. For example power control influences the Carrier to Interference (C/I) values of the network and thus dynamic channel allocation and handover algorithms and vice versa. The test of algorithms with constant parameters is not adequate in this case since only isolated cases can be observed.

A third new approach is the actual value interface (AVI) that has been developed in the ACTS projects sponsored by the European Union. In this approach actual link level parameters are imported via an interface.

We use for our system level simulation tool MOSIT an adaptive bit error generator. With standard path-loss and fading models the C/I-ratio is computed for every link. The bit error ratio for raw uncoded transmission $\{b_k\}_{in}$ -$\{b_k\}_{out}$ [Figure 1] is determined from (E_b/N_0)/BER graph using the calculated carrier to interference level. This (E_b/N_0)/BER lookup tables have to be generated in separate link level simulations. Another possibility would be to use a (E_b/N_0)/RER rest error rate graph for encoded data transmission to determine only the rest error ratio as shown in path C. The disadvantage of this method is that the delay of hybrid ARQ II schemes cannot be modelled. On the other hand, no calculation of channel coding and decoding is needed.

The simulation of dynamic channel allocation and handover protocols but also error correction procedures like hybrid ARQ II schemes requires this link level parameter. One problem with our solution is that modern decoders need soft-decison values and channel state information. These cannot be modelled accurately this way. We have to assume a constant gain of *x* dB for simulation models with soft-decision decoders or we have to use the bit error ratio values to model a reliability estimation.

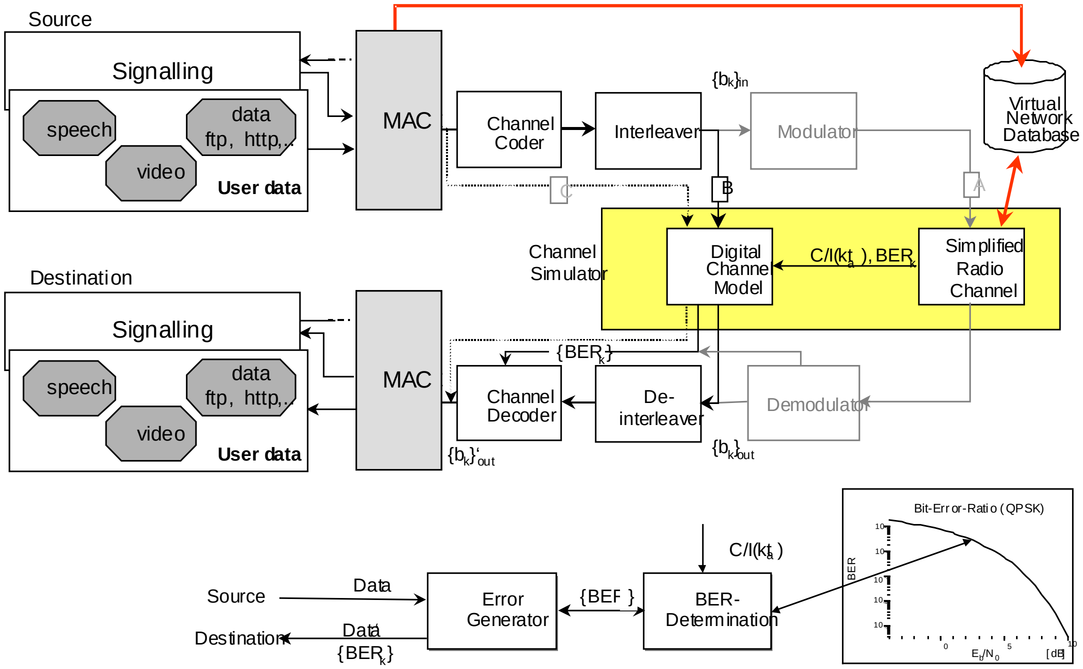


Figure 1: Model in the system level simulation for one transmission link

The simulation tool shall allow to reproduce the test environment (or the virtual network) for the comparison of different channel allocation algorithms. To examine the impact of channel allocation algorithms on the network load, it is required to model changing network conditions including moving mobiles and traffic generators. When evaluating new protocols the user data source coders can be omitted.

2 Simulation

2.1 Simulation with SDL

Our system level simulation tool MOSIT is written in SDL (Specification and Description Language, ITU-recommendation Z.100) using the well known SDT tool. The generation and simulation of communication protocols with SDL is straightforward and efficient. The concurrent design of large systems with several developers becomes considerably simplified because of the highly modular graphic user interface of SDL an clearly defined interfaces between processes. Since SDL supports documentation on the fly the reusability is much better than for example with C-Code. The SDL code is automatically converted into C code and can be compiled for many platforms with the SDT-tool.

2.2 Virtual Cellular Network Environment Model

The simulation model is initialised with parameter files for an arbitrary number of base stations with individually adjustable parameters. Mobile stations are placed randomly or with pattern files. Each mobile station changes the direction and the speed randomly within adjustable parameters or controlled via movement pattern files. The complete data basis for the simulation of the virtual network is kept in a central data base.

The activity of the mobiles is controlled by a traffic generator. This traffic generator contains models for speech, video (constant bitrate) and data services (variable bitrate).

Measured time series for the respective locations and speed can be read via pattern files. For each base station antenna sector, frequencies and channels can be assigned. The frequency and channel allocation can either be static or dynamic. Hierarchical cell structures can be built according to the adjusted transmitting power.

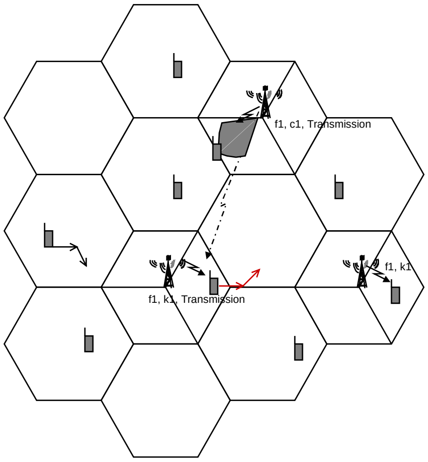


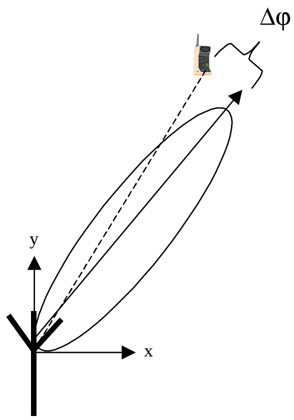
Figure 2 Virtual Cellular Network

2.3 Propagation model

Each mobile station regulates its transmitting power with the support of the serving base station. In most cases that is the one with the strongest broadcast carrier. This transmitting power regulation is carried out by the asynchronous and decentralised CIR based IPC-algorithms [2], which has proven to be very robust in the simulation. At the moment three standard path-loss models are implemented to predicted the carrier to interference level. We use indoor, vehicular and pedestrian (indoor to outdoor) models, which have been evaluated by ITU-R Task Group 8/1. The implemented lognormal distributed slow fading model has been suggested by D. Huo (ARMA Auto-Regressive-Moving-Average Markovian model of order (1,2)) with moving shadowers [4]).

2.4 Modelling Antennas for System Level Simulation

Dynamically adjustable antenna diagrams and transmitting sectors can be assigned to the antennas of the base stations. The directional models and algorithms for adaptive antennas have to be simplified for system level simulation. There are two effects that have to be considered: inaccuracies because of the estimation algorithms and “misdirected” beams. We do not model the real environment of therural or urban area. Therefore we use no rays and strong scatterer. The DOA (direction of arrival) estimation is idealised and the antenna beam is directed towards the ideal direction - the position of the mobile station. In reality the antenna can also be directed on a strong scatterer especially in cases of none line of sight. Measurements have shown quite a good accuracy of the angle estimation of adaptive antennas with low standard deviation [11]. The standard deviation of most estimation algorithms is quite highcompared to the inaccuracies of measured DOAs [Figure 3].
We assume that the slow fading process and the path-loss model takes the effect of the orientation towards strong scatters sufficiently into account. For a system level simulation of higher layers it is much to complex to consider the effects of “misdirected antennas” towards a strong scatterer [Figure 4].



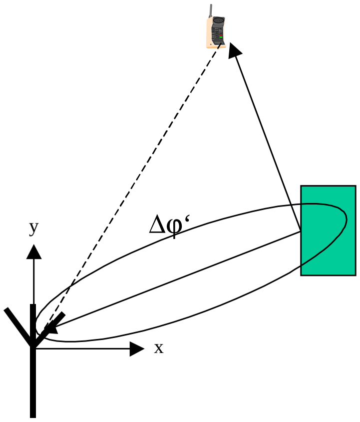


Figure 3: Inaccuracy of the DOA estimation **Figure 4:Strong scatter**

Only the estimation errors of the DOA estimation algorithms are modelled with a standard deviation depending on the algorithm that is assumed. In the case of considering switched antennas the discrete positions have to be taken into account.

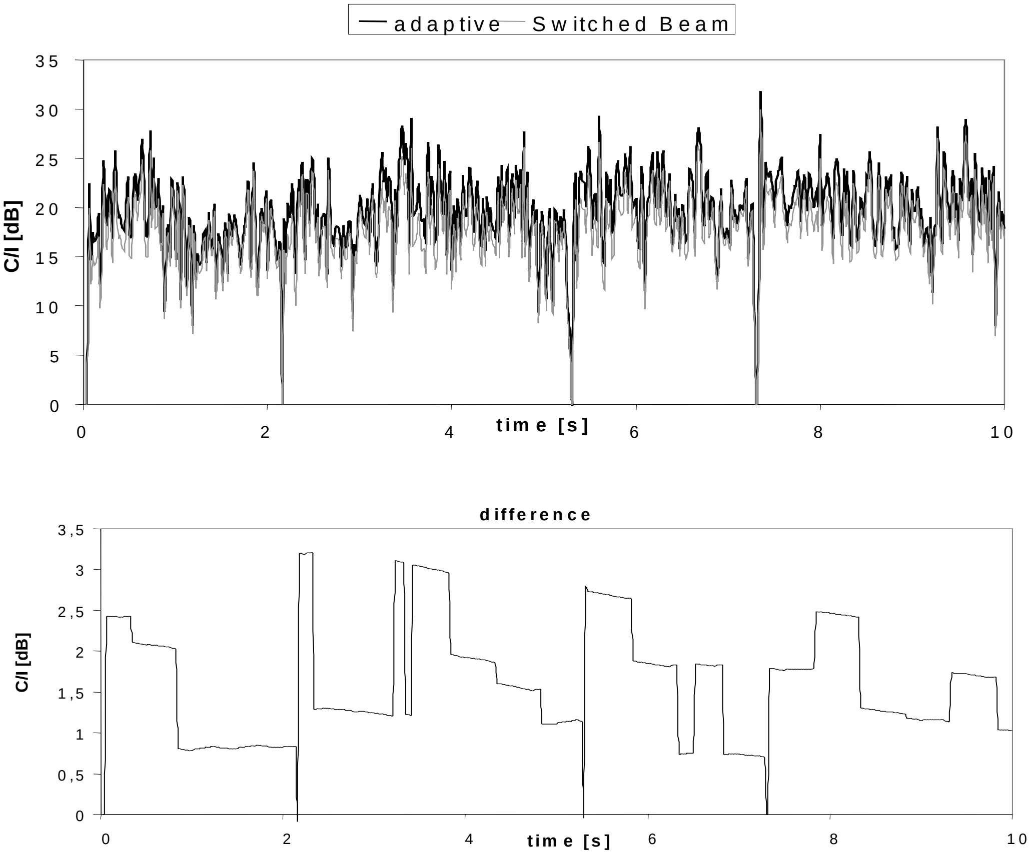


Figure 5: Comparison of switched beam and phase array for a given scenario

We use two models for adaptive antennas. One is based on the description of phased arrays with *M* sinus or omnidirectional elements. With this model the beam can be modelled and steered in a correct way but there is no consideration of nulling the interference or multipath rays with the side lobes possible. For that purpose a complex directional description with multipath rays and complex beam steering algorithms would be necessary (SFIR). The loss of beams that are not directed in the optimal direction (right angle to the phased array) is assumed to be compensated by the power control algorithm. An enhancement could be achieved by limiting the maximal power depending on angle relative to the array.

Phased array beam form $F(\theta)$ are described by [14]:

$$f_g(\theta) = \frac{\sin\left(M \cdot \frac{\pi}{2}(\cos\theta - \cos\theta_0)\right)}{M \cdot \sin\left(\frac{\pi}{2}(\cos\theta - \cos\theta_0)\right)} \tag{3.1}$$

$$F(\theta) = f_g(\theta) \cdot g_E(\theta) \tag{3.2}$$

where $g_E(\theta)$ is a characteristic of the single element of the antenna array and $f_E(\theta)$ describes the group faktor.

$$g_E(\theta) = \begin{cases} \sin\theta & , 0 < \theta < \pi \\ 0 & , \text{ otherwise} \end{cases} \tag{3.3}$$

The Antenna gain G can be assumed to be $G = 10 \cdot \log(M)$ (M elements).

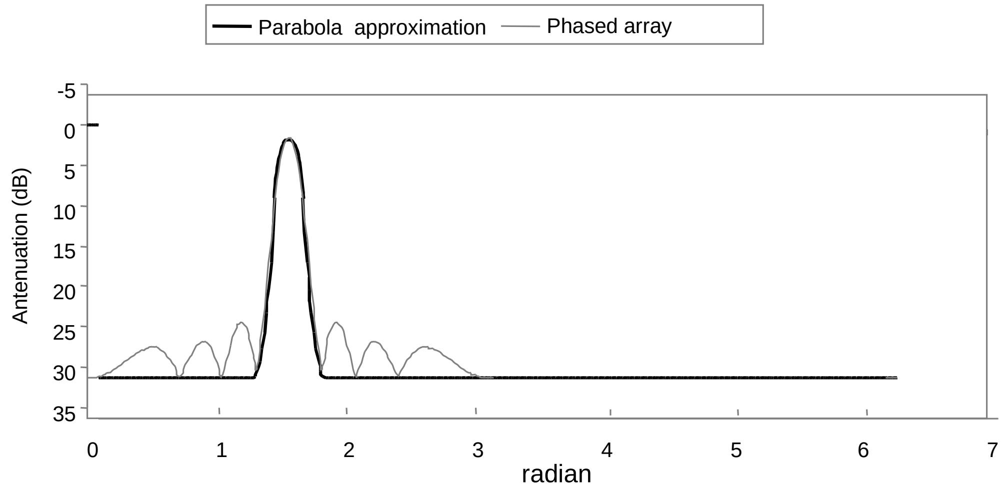


Figure 6: Phased array and parabola aproximation

For a second smart antenna model we assume ideal interference cancellation. The main beam is approached with parts of parabolas that can be configured in width with parameter pattern files. The side lobes are set to a constant attenuation value. The reduction of multipath rays can only assumed to a constant gain depending on the local environment that has to be evaluated in more accurately simulations or measurements. An other possibility would be a new model for a adapted rayleigh fading process.

3 Estimation Error for Positioning Algorithms

The DOA estimation of adaptive antennas can be used for the evaluation of the mobiles location [11] . Therefore the inaccuracy of the location estimation has to be estimated and delivered to for example handover algorithms. In this model normal distributed scatterer [14] are determined and the ray with the shortest distance between mobile station and base station is used for the angle estimation. The scattering radius R depends on the assumed area With the lowest DOA angle and a virtual timing advance the position can be estimated in a certain accuracy. In the case of line of sight (LoS) the direct path is assumed to be considered. The decision of the existence of LoS or NloS (NonLOS) is based on a threshold and a uniform distribution. It has to be observed if this model should be enhanced with a lognormal distibuted correlation time.

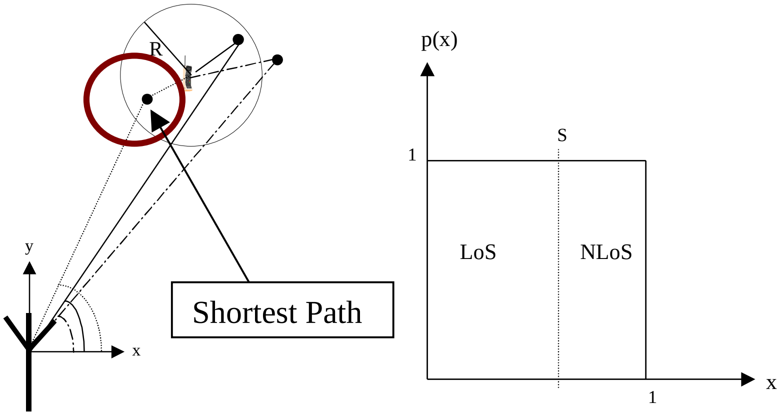


Figure 7 : Location estimation and LoS/NLoS threshold

4 Handover Protocol For Smart Antennas

First a handover algorithm based on a simple procedure using the transmission power of the strongest broadcast channels of the neighbouring base stations was implemented. To prevent fast hopping between two base stations was used a simple handover hysteresis. A second more enhanced model has been implemented with layered hierarchical cell structures. The decision for an handover can be based on speed, path-loss and link quality. The speed calculation is applied under the idealised assumption that the doppler shift is known and delivers the speed.

One first step to an enhanced handover protocol is the observation of the link quality. If two beams move closer to each other the C/I values decrease. Is the observed link quality too bad for a given time window our algorithm tries to adapt the actual channel allocation. If that fails the actual channel is lost.

Next step will be a more enhanced model using the estimated positions of the mobile station and the link quality. The direction of arrival (DoA) estimation of adaptive antennas of the antenna can be combined with long-term predictions of the movement of the subscriber. In that case the network has to learn movement pattern that are quite regular for most people. Is the actual position correlated with the movement pattern the direction of the movement can be predicted. In that case capacity can be reserved in the next cell to reduce call blocking due to handover (enhancement of the GoS).

Other suggestions can be found in the literature which use correlation of measurement reports of the mobile for example. Two methods of estimating the actual position are currently under research.

The direction of arrival (DoA) estimation of adaptive antennas can be used for short-term predictions whereas long-term predictions can be done with methods that have knowledge of the user´s normal behaviour in time and location, applying for example neural networks [3].

With the knowledge of the next predicted cell, capacities can be pre-reserved and prioritised for the mobile in advance to reduce the blocking rate and signalling.

5 Conclusions

The paper points out a possible way of simulating system level protocols using simplified antenna models for sector or smart antennas. As complete link and system level simualtions are much to complex for state of the art computers it is important to implement this algorithms efficiently. With our simulation library we are now able to simulate new protocols that have to be developed with the introduction of new features, e.g. space diversity multiple access (SDMA) [8] into next generation networks. Our next step will be the testing of advanced handover protocols that use the DoA estimation of adaptive antennas to predict the movement of mobiles. At the moment we use a qualtity based approach. Much more work has to be done on handover and channel allocation strategies for smart antennas. Especially for TD-CDMA and W-CDMA are many scenarios possible for beamforming. Handover algorithms can suffer from communication protocols between the base stations.

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Apendix

First Examples (GSM like System) mean values (1000 samples, 10 sec)

MS16		CIR[db]	Pe[dBm]	Ps[W]
Phased array	down	22,72	-94,64	0,33
Parabola approximation (optimal SFIR)	down	24,27	-93,09	0,30
Sector antenna	down	22,72	-94,64	0,33
Phased array	up	24,47	-94,81	0,09
Parabola approximation (optimal SFIR)	up	24,47	-94,81	0,09
Sector antenna	up	22,89	-96,39	0,13

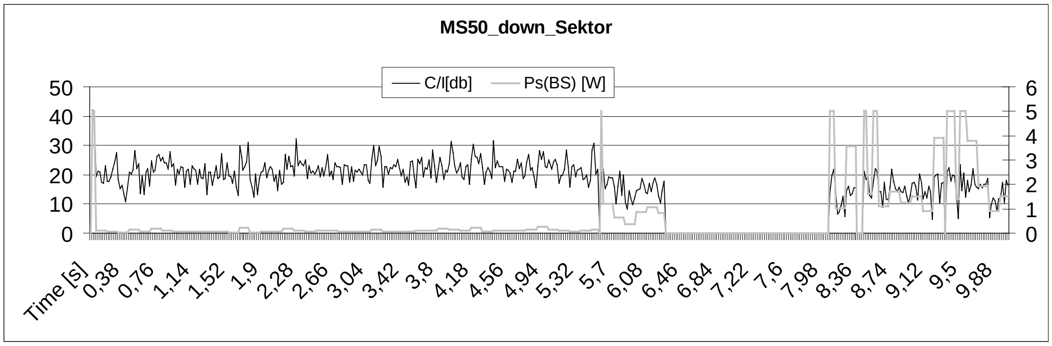
MS36		CIR[db]	Pe[dBm]	Ps[W]
Phased array	down	9,54	-51,42	0,42
Parabola approximation (optimal SFIR)	down	9,59	-51,37	0,37
Sector antenna	down	7,35	-53,61	1,03
Phased array	up	7,42	-54,74	0,44
Parabola approximation (optimal SFIR)	up	8,20	-53,96	0,39
Sector antenna	up	1,65	-60,51	0,50

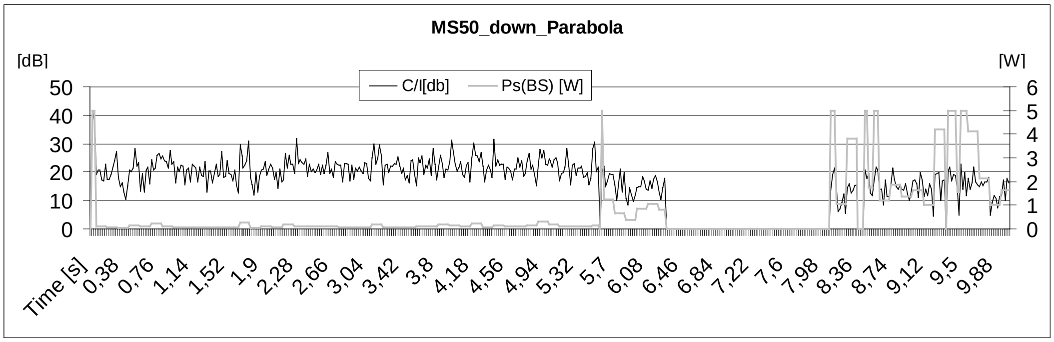
MS50		CIR[db]	Pe[dBm]	Ps[W]
Phased array	down	15,90	-81,06	0,61
Parabola approximation (optimal SFIR)	down	15,71	-81,25	0,64
Sector antenna	down	13,15	-83,81	1,22
Phased array	up	17,10	-80,58	0,25
Parabola approximation (optimal SFIR)	up	16,95	-80,73	0,25
Sector antenna	up	14,37	-83,31	0,36

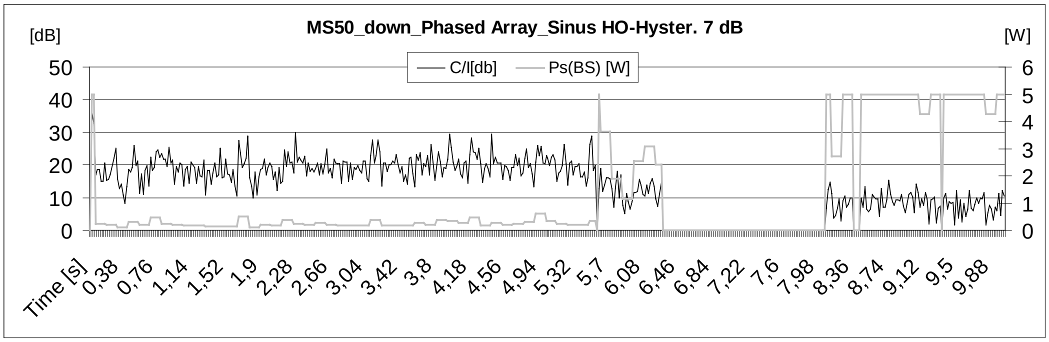
Assumptions for first simulations (next side)

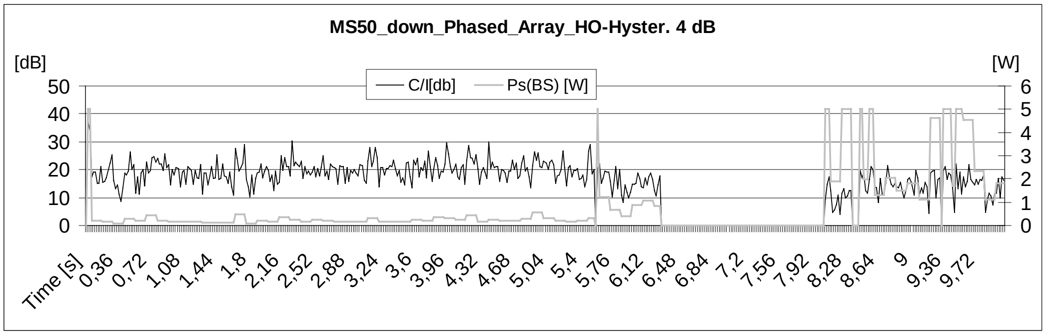
	antenna gain	P_{sMS} [W]	P_{sMaxBS} [W]	elements	HO-hysteresis
Phased array	0 dbi / (9dBi)	1	5	8	7 dB (4 dB)
Parabola approximation	0 dbi	1	5	8	7 dB
Sector antenna	0 dbi	1	5		7 dB
4 base stations, 3 sectors, 2 frequencies and 3 channels per frequency, C/I based slow power control,					

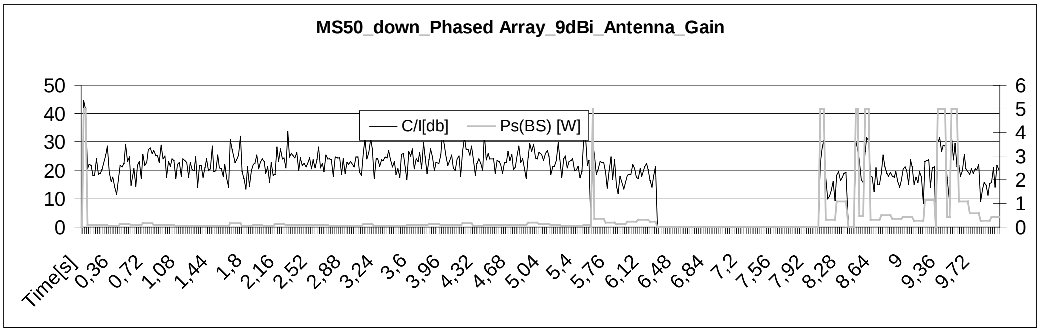
Exemplary simulation results:


MS50_down_Sektor


MS50_down_Parabola


MS50_down_Phased Array_Sinus HO-Hyster. 7 dB


MS50_down_Phased_Array_HO-Hyster. 4 dB


MS50_down_Phased Array_9dBi_Antenna_Gain

Accuracy of DOA estimation algorithms:

	Algorithm	Standard deviation	Literature
Simulation -SNR variabel	TR-Algorithm 20dB<SNR<40dB training's sequence: 26 Bit $\Delta=0^\circ$	6° - 8°	[14]
Simulation -SNR variabel	TR-Algorithm 20dB<SNR<40dB training's sequence: 52 Bit $\Delta=0^\circ$	1.5° - 2.5°	[14]
Simulation -SNR variabel - Δ variabel	SR-Algorithm 10dB<SNR<30dB without training's sequence $\Delta=0^\circ$	< 2°	[14]
Simulation - SNR variabel - Δ variabel	SR-Algorithm 10dB<SNR<30dB without training's sequence $\Delta=1^\circ$	< 4°	[14]
Simulation - SNR variabel - Δ variabel	SR-Algorithm 10dB<SNR<30dB without training's sequence $\Delta=3^\circ$	< 6°	[14
Simulation - SNR variabel - Δ variabel	SR-Algorithm 10dB<SNR<30dB without training's sequence $\Delta=7^\circ$	10° - 17°	[14]
Simulation	MEM,SLP Phase- and Amplitude errors	1°	[13]

Δ angle spread