동적 핸드오프와 전력제어를 고려한 적응배열 시스템의 네트워크 시뮬레이션*

System Level Network Simulation of Adaptive Array with Dynamic Handoff and Power Control

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Abstract

In this study, the system level network simulation is considered with adaptive array antenna in CDMA mobile communication system. A network simulation framework is implemented based on IS-95A/B system to consider dynamic handoff, system level network behavior, and deploying strategy into the overall CDMA mobile communication network under adaptive array algorithm. Its simulation model, such as vector channel model, adaptive beam forming antenna model, handoff model, and power control model, are described in detail with simulation block. In order to maximize SINR of received signal at antenna, Maximin algorithm is particularly considered, and it is computed at each simulation snap shot with SINR based power control and handoff algorithm. Graphic user interface in this system level network simulator is also implemented to define the simulation environments and to represent simulation results on real mapping system. This paper also shows some features of simulation framework and simulation results.

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I. Introduction

The system level network simulation of a mobile communication system is theoretically able to investigate the performance in terms of capacity, handoff and power control.[1][2][3]. System level network simulation is being studied for evaluating the network performance such as coverage area, service quality metric, capacity and so on without any installation of base stations before deploying network infrastructure[4][5]. By some prior study[6][7], the optimization of cell parameters are considered by simulating the network behavior. It is also considering the design optimization of cell location by simulating the wireless network with cells on real world map[8].

In the other hand, at cellular base station in wireless CDMA network, it is known that capacity increase is achievable by applying adaptive beam forming algorithm. Although an adaptive beam-forming algorithm developed is so innovative as to enlarge the capacity, the most important innovations will be in integrating this algorithm into the network architecture[9]. Therefore, system level network simulation is necessary for investigating the behavior of network when applying adaptive array beam forming antenna. Particularly, the simulating the network behavior by modeling CDMA(code division multiple access) mobile communication cellular network can do evaluating the network performance under circumstances of multi-base stations, multi-mobile stations with mobility, and under fading channel environments. Even theoretical system level simulations on this performance evaluation appear to be more successful because large network system and test environments are required to evaluate practically[10].

For system level network simulation framework, it also has system level receiver model of base stations and mobile stations with mobility, that will allow the adaptive beam forming algorithm to be investigated with handoff and power control considerations. In this study, system level network simulation framework is developed by its receiver model to simulate the CDMA cellular network with graphic user interface. It is considering primarily IS-95A/B with various signal parameters[11].

With this simulation framework implemented by this study under various simulation circumstances, we can do considering the behavior of a wireless CDMA network when applying adaptive array. It will help to understand the operations of adaptive array beam forming antenna when it is integrated into the network architecture with dynamic handoff and power control in wireless CDMA network such as IS-95A/B. For this simulation purpose, the simulation framework, simulation environment, and simulation parameters are defined based on IS-95A/B, first. Propagation channel model with mobility, array antenna model by adaptive beam forming algorithm, power control, and handoff model, are described next. Some features and simulation results are shown. This paper also concludes with a brief summary

II. Simulation Skeleton

A. Simulation Framework

Simulation framework is primarily implemented based on IS-95A/B system to consider network capacity, handoff and power control. In this simulation framework, multi-base stations and mobile stations are considered, which are placed by letting user locate them on real map with MapX interface[12].The simulation framework for system level network simulation has graphic user interface on GIS(Global Information System) for users to locate base stations and mobile stations to consider exact behavior of network[13]. It is also considering each mobile station in up and down links on each location with adaptive beam forming algorithm.

This system level network simulation framework is built to consider cellular network behavior when applying adaptive beam forming antenna in CDMA cellular network. First of all, tele-traffic model, mobility model is to be defined for call generation in order to investigate system level network behavior. Radio link between base station and mobile station is also defined by multi-path vector channel containing propagation model and interference model in multi-user environment[14]. At cellular base station in CDMA mobile communication system, adaptive array beam forming antenna is applied to increase its capacity, which is modeled by adaptive algorithm referenced by prior research [15][16]. CDMA cellular network generally has deployed power control and handoff, which is operated by instantaneous SINR (signal to interference plus noise ratio), measured at receiver. For calculating SINR and radio link level, a snap shot calculation is to be made at every power control group with mobility. At the stage of representing

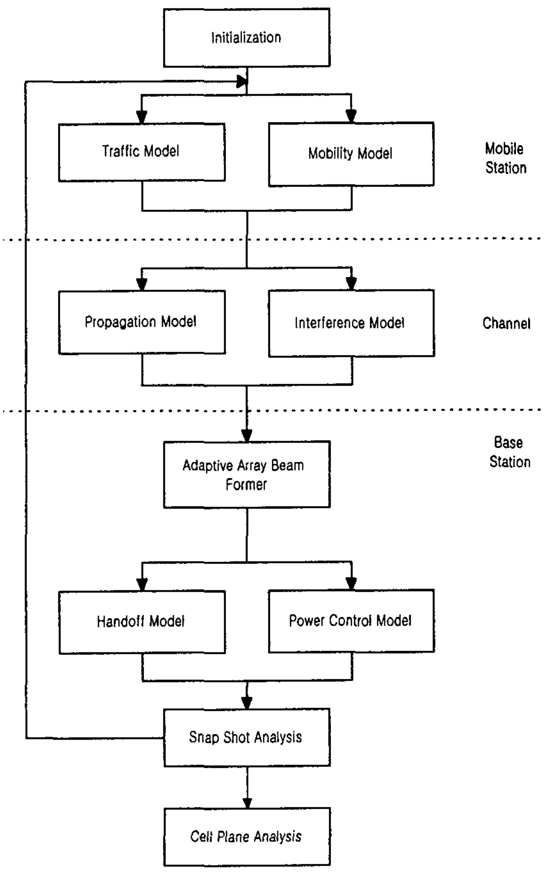


Fig. 1. Simulation framework for CDMA mobile communication network

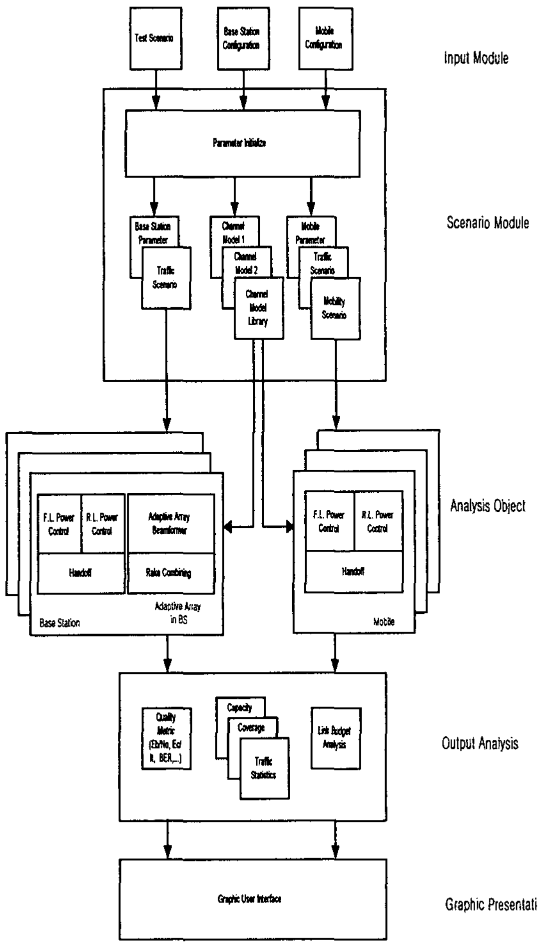


Fig. 2. Modular structure of simulation block

simulated results, graphic user interface is provided for monitoring and representing up and down link. Simulation framework in CDMA mobile communication system is shown in Fig. 1.

Object oriented modular structure of simulation models is more effective for easy change of system architecture along the progress of standard activities. Therefore, it is programmed by object oriented components as Fig. 2.

Tab. 1. Simulation Environment and its parameter

Simulation Environment	**Environment Parameters**	**An Example of Environment Parameters**
Dimension of BS and MS	Max. number of mobiles generated Number of base stations (sectors)	2000 MS randomly generated 12 Cell (36 Sectors)
Simulation interval	Simulation snap shot	1.25msec
Path loss model parameters	Hata coefficients Log normal shadowing STD Rayleigh fading STDmax	-125.777-35.041log10(R) -6.5[dB] -8.0[dB]
Mobility/tele-traffic model parameters	Number of turning direction Turning rate Vehicle speed Speed change rate Call duration	16 Directions 60/Min 10 ~ 50 Km 60/Min 30sec
Handoff model parameters	T_Add T_Drop T_Tdrop T_Comp	-12 [dB] -14 [dB] 5 [sec] -2.5 [dB]
Power control parameters	Power control step size Power control error rate Power control delay BigUp_Forward SmallUp_forward PowerDown_forward	1[dB] 3[%] 1[command] 0.03[Watt] 0.007[Watt] 0.0003[Watt]
Initial power and Eb/No	Total Tx Power at cell Pilot Ch. Power Paging Ch. Power Sync Ch. Power Traffic Ch. Power Set Eb/No Max. Mobile Power	25[Watt] 3.02047 [Watt] 0.449873 [Watt] 0.112998 [Watt] 0.3487 [Watt] 7.5 [dB] 0.6 [Watt]

B. Simulation Environment and Parameters

1. Simulation Environment

The system level network simulator is built to investigate system level behavior such as handoff, power control with adaptive array beam forming antenna under given simulation environment. The simulation framework is considering SINR based power control and mobile assisted handoff, therefore, individual SINR or link level components are computed at each snapshot of power control group under mobility and traffic load environment. The followings are possible simulation environments of the simulator developed in this study;

The simulation environment is to be defined interactively on a real mapping system of GIS by a user. Each simulation environment is selected by profile configuration sheets, which are consisted of network configuration, sector/cell configuration, mobile configuration, and channel configuration. The user can also define the interval of each calculation snap shot, total simulation period and refreshing interval of display in graphic user interface. An example of environment parameters is shown on Tab. 1.

Tab. 2. Simulation parameters and representation in simulation results

Parameters		Representation in simulation results
Quality metric	Eb/No	Bit mapped display and time graph at each cell selected
	Ec/It	Bit mapped display and time graph at each cell selected
	FER	Time graph for FER at each cell selected
Traffic quality statistics	Call success rare	Ratio of sucees call to total call generated and display of generated position on map
	Call drop rate	Ratio of dropped call to total call generated and display of dropped position on map
	Call block rate	Ratio of blocked call to total call generated and display of blocked position on map
	Active mobiles	Time graph at each cell selected
Coverage, capacity	Forward link coverage	Bit mapped display
	Reverse link coverage	Bit mapped display
	Capacity	Time graph for # of success call at each cell selected
Handoff	Soft handoff region	Bit mapped display
	Softer handoff region	Bit mapped display
Link budget	Propagation loss between BS and MS	Bit mapped display and time graph at each cell selected
	Rx power received at MS	Bit mapped display and time graph at each cell selected

2. Simulation Parameters

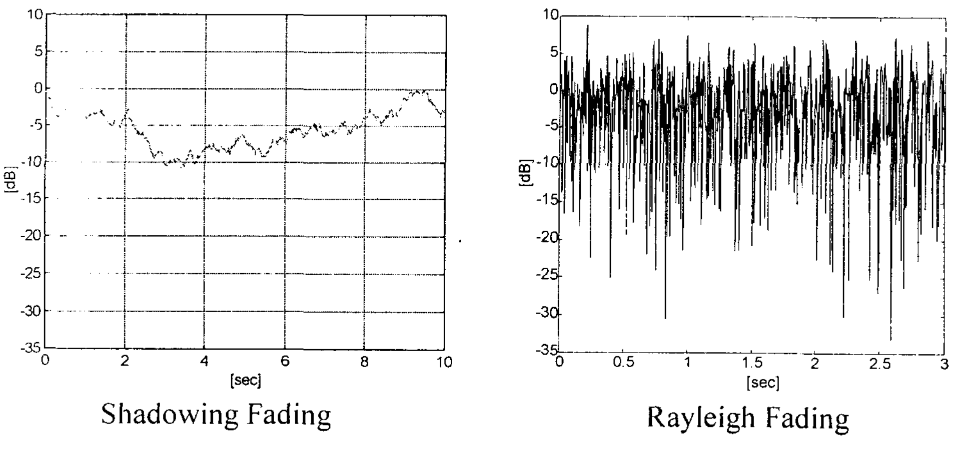
After computing each quality metric component to be used in evaluating the performance of network under adaptive array beam forming antenna, it is represented by pseudo-colored dot on the display of real mapping system of GIS. Parameters on Tab. 2 are simulation parameters to be computed for evaluating the performance of developed algorithm, and for comparing it with other algorithm under a certain simulation environment.

III Simulation Cockpit Model

A. Propagation Channel Model

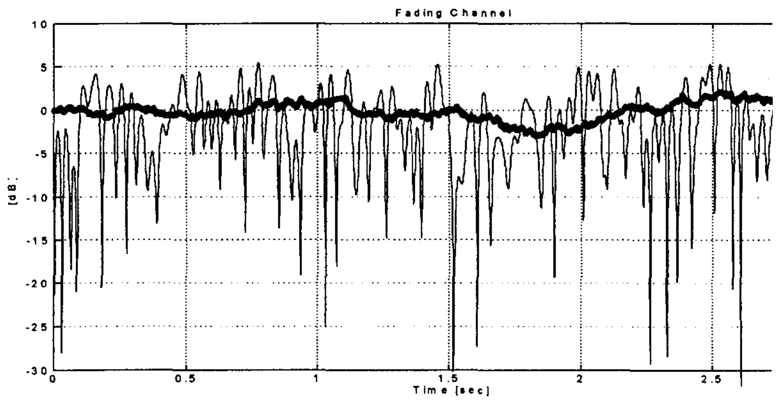
In this system level network simulator, we are considering theoretical vector fading channel. Theoretical channel model implemented is shown by Fig. 3, such as Hata-Okumura propagation model, Rayleigh fading channel model and log-normal shadowing model, which are modeled by a vector channel concept referenced by prior papers[14][17].

The vector channel response generated provides a multi path delay profile with temporal resolution depending upon the probing bandwidth used to estimate the channel, which also provides independent fading envelope on each multi-path for each antenna element. Fig. 4 is typical scattering environment to be used in vector channel model. In this simulation framework, vector channel model is modeled and implemented with some statistical assumption such as the number of scatters, the position location of scatter, scatters' reflective coefficients and so on.



(a) Log-normal shadowing channel

(b) Rayleigh fading channel



σ = 8 [dB], V_m = 20 [km/h]

(c) Combined channel response by theoretical channel model

Fig. 3. Theoretical channel models

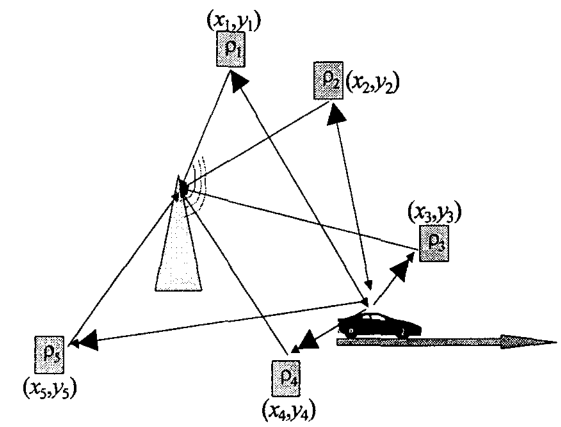


Fig. 4. Typical scattering environment to be used in vector channel model.

B. Handoff and Power Control Model

The system level network simulator is being built to investigate network performance with handoff, power control under adaptive array beam forming antenna under given simulation environment. The simulator is based upon SINR based adaptive beam forming algorithm to maximize SINR for each link between base and mobile station at simulation snap shot. SINR based power control components and mobile assisted handoff components are also computed at each snapshot of power control group after applying mobility and traffic load environment with a beam pattern of adaptive array antenna.

1. Handoff Model

In system level network simulator, adaptive beam forming algorithm is implemented for providing antenna radiation patterns to maximize the signal to interference plus noise ratio (SINR). Mobile assisted handoff, affected by SINR based power control and by radiation beam pattern from adaptive beam forming algorithm, is computed and updated at every simulation snap shot. Handoff algorithm based on IS-95A/B is primarily implemented by SINR basis in mobile station. As mentioned above, in this system level network simulator, dynamic handoff algorithm is considered by adaptive beam forming algorithm.

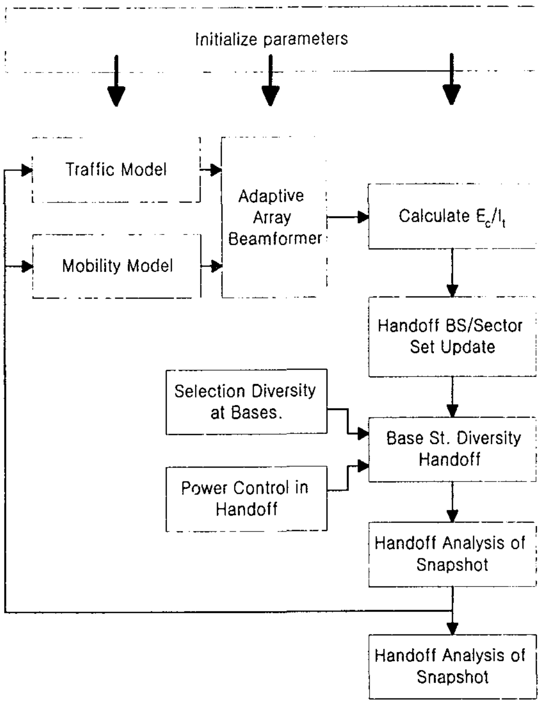


Fig. 5. The block diagram for handoff model

In IS-95A/B system, selection diversity for up-link, and cell diversity for down-link are considered respectively. Therefore, these two diversity features are implemented in system level network simulator with adaptive array antenna beam forming. During handoff, SINR based power control algorithm, different from that of non-handoff state, is also applied by which mobile station execute smaller command among two power control commands for reducing power in handoff state.

2. Power Control Model

In CDMA system, power control is very effective to solve near-far problem. In system level network simulator, SINR based power control system is also implemented with adaptive beam forming algorithm.

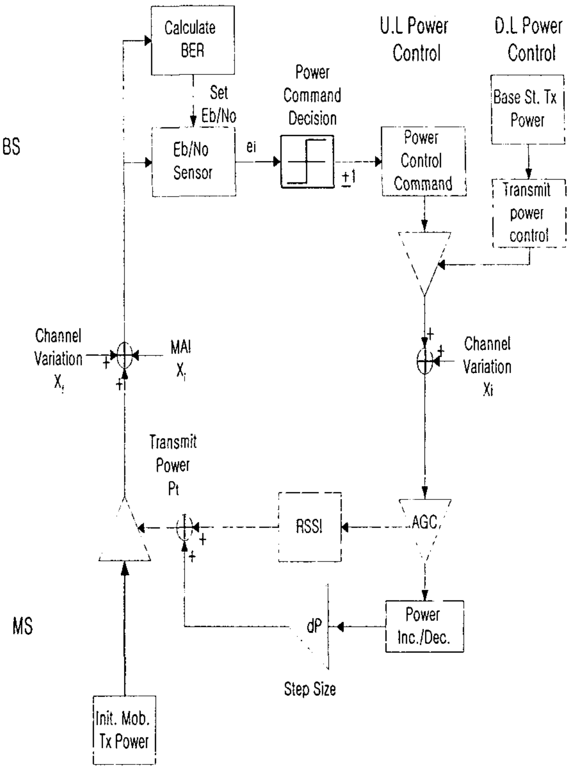


Fig. 6. Block diagram of SINR based power control model

In this network simulator, power control algorithm based on IS-95A/B is primarily implemented by sensing SINR at base station. During handoff, SINR based power control algorithm, different from that of non-handoff state, is also implemented in this simulator by which mobile station execute smaller command among two power control commands for reducing power in handoff state. In network simulator, power control is applied to both links, which includes open loop power control, closed loop power control, and outer loop power control. The block diagram for power control model is shown in Fig. 6.

Open -loop power control and closed loop power control are defined as follows respectively;

- Open loop power control model:

$$P_o = k - P_r$$
$$P_{to}(t) = P_o(1 - \exp(-t/\tau))$$

P_0 : Mobile TX Power Estimate
P_{to}: Mobile Output TX Power
P_r: Mobile RX Power
k : Turn Around Constant
τ : Time Constant in Open-loop Power Control

- Closed-loop power control model:

$$p_{i+1} = p_i - \Delta P \cdot C(E_{i-k})$$
$$E_{i-k} = P_{i-k} + X_{i-k} - \delta_{i-k}$$

$$C(E_{i-k}) = \begin{cases} +1 & if \quad E_{i-k} < 0 \\ -1 & if \quad E_{i-k} > 0 \end{cases}$$

p_{i+1} : Tx Power transmitted at i-th stage by MS
ΔP : Power step size of closed loop power control
$C(E_{i-k})$: Power control command from BS at i-th stage with k-th delay
E_{i-k} : Decision output of power control by BS
X_i : Multiple access interference measured at BS in [dB]
P_i : Rx Power received at i-th stage by BS in [dB]
δ_i : Eb/No Set point at BS for power control in [dB]

C. Antenna Beam Pattern by Adaptive Beam Forming Algorithm

In system level network simulator, adaptive beam forming algorithm is implemented by providing radiation antenna beam patterns to maximize the signal to interference plus noise ratio (SINR). Radiation beam pattern by adaptive beam forming algorithm is computed and updated at every simulation snap shot based on SINR from arrived signal, noise and multiple access interference (MAI).

We have implemented adaptive array beam pattern module, which is applicable to fixed radiation beam profile based on IS-95A/B. We are working on implementing adaptive array algorithm on radiation beam pattern module by replacing fixed beam module with adaptive array beam forming. Antenna beam pattern module is being built to consider adaptive array beam forming by Maximin algorithm to maximize SINR first, which is also adaptable to SINR based power control and handoff.

1. Maximin Adaptive Array Algorithm

The Maximin algorithm is a novel approach to blind adaptive beam forming that is applicable to CDMA mobile communication system.[18][19] The algorithm was originally developed for maximizing the signal to interference plus noise ratio (SINR) for frequency-hopping signals and originally worked only for time-gated signals. This algorithm has been extended to handle CDMA.[18]

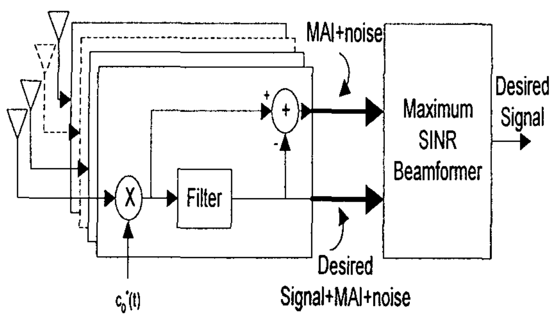


Fig. 7. Maximin concept for CDMA beam forming

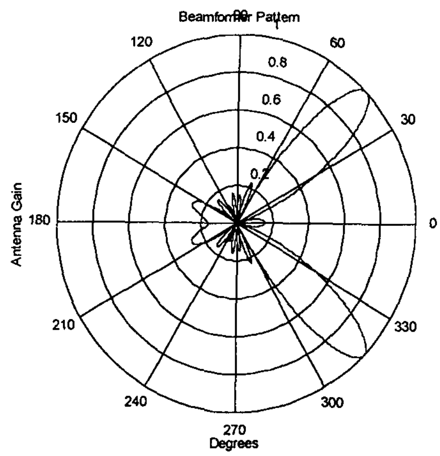


Fig. 8. Expected antenna beam profile when implementing adaptive beam forming algorithm

The Maximin algorithm is a blind algorithm that does not require the knowledge of the array manifold, or precise array calibration[15] [18]. Its convergence is faster compared to that of the commonly used blind algorithms such as constant modulus algorithm (CMA) or decision-directed algorithms (DDAs) [18] [20], and it is comparable to that of non-blind algorithms[20]. Also, the Maximin algorithm is guaranteed to converge to the desired solution unlike the other blind algorithms[20]. The Maximin algorithm is also suitable for the adaptive beam forming with CDMA signals and can be used for burst acquisition and code timing synchronization[16].

Detailed Maximin algorithm referenced by prior paper[15] shows that a code-gated Maximin algorithm can also be designed for the CDMA signals in addition to time and frequency-gated implementations of the Maximin algorithm. At the CDMA receiver, after the received wide band CDMA signal is multiplied with the desired user's spreading code, the result is a narrow band signal of the desired user in the wide band multiple access interference. The conventional CDMA receiver filters the desired narrow band signal for further processing. In the code-gated Maximin algorithm, the MAI is also processed for estimating the correlation properties of the interference and the noise. Fig. 7 is Maximin concept for CDMA beam forming.

Fig. 8 represents expected antenna beam profile from adaptive array beam forming antenna after implementing adaptive array algorithm in adaptive array beam pattern module.

IV. System Level Network Simulator

A. Control Flow of Simulator

A simulator is being created to consider the interaction of adaptive arrays with handoff algorithms for CDMA mobile communication system. The simulation is primarily based on IS-95A/B handoff and power control algorithms with dynamic link coverage, computed by Ec/Io when the adaptive array is applied. This simulator will include vector channel model between base station and mobile station to simulate more accurate channel.

In this handoff simulation framework, user can specify the orientation of array and mobility of mobile. Then the impulse response of the channel is estimated for each location of the mobile station (MS) at spatial domain by vector channel model. Once the impulse response of channel is estimated for a given position, Eb/No received at this MS location with adaptive array, are estimated and compared with the handoff threshold. As the MS is traveling along a direction by mobility, this procedure is updated at each location.

The simulator will allow us to investigate the effectiveness of adaptive beam forming antenna algorithm using a CDMA system model that includes handoff, power control, and vector channel models. The simulator will provide insight into developing new adaptive array algorithms and how the adaptive array should be integrated into the overall network. The simulation concept in system level network simulator is shown in Fig. 9. Detailed system level network simulation flow diagram is also shown in Fig. 10.

The simulation steps are outlined as follows;.

Step 1: ***Define base station location by user or systematically define base station location by predefined patterns such as hexagonal distribution and rectangular distribution.***

Step 2: ***Define initial service coverage by an equal-distance border.***

Step 3: ***Generate randomly a MS inside each cellular coverage boundary with an initial location and initial velocity and direction.***

Step 4: ***Calculate Eb/No in base station and mobile station with inter-cell interference and intra-cell interference and calculate exact cellular boundary at that instance. This is one snap shot of simulation.***

Step 5: ***Move each mobile station by mobility model in which velocity change and direction change are considered***

Repeat Step 4. and Step 5. and simulate handoff/power control performance.

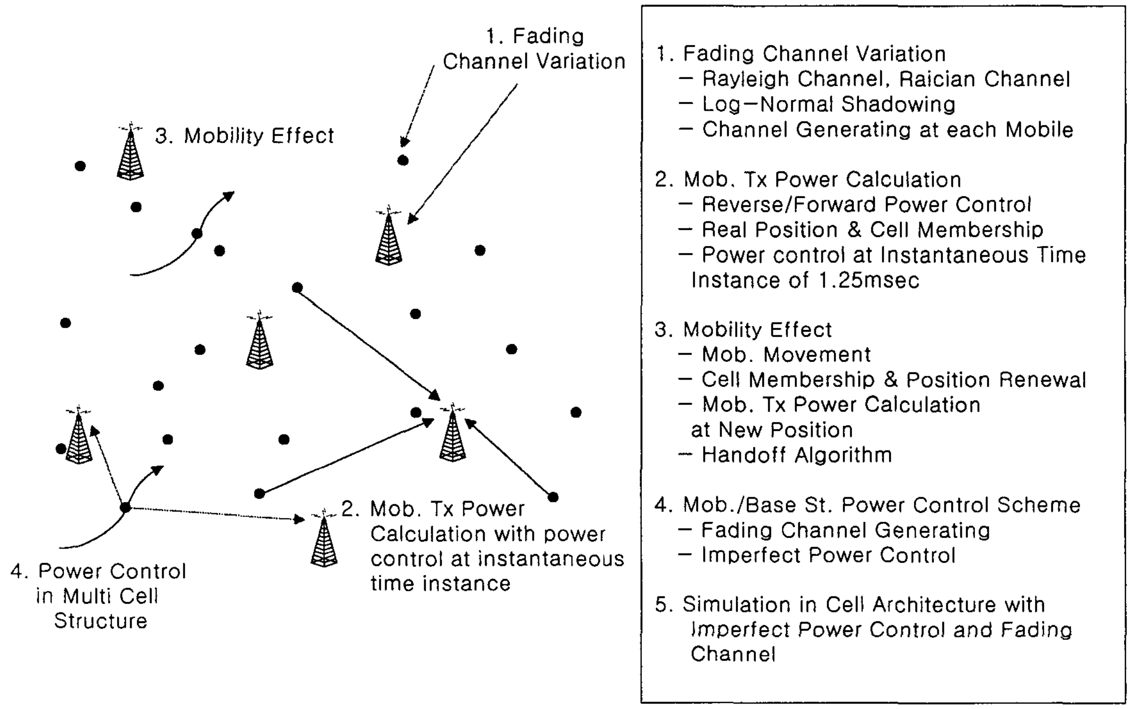


Fig. 9. Concept of system level network simulation

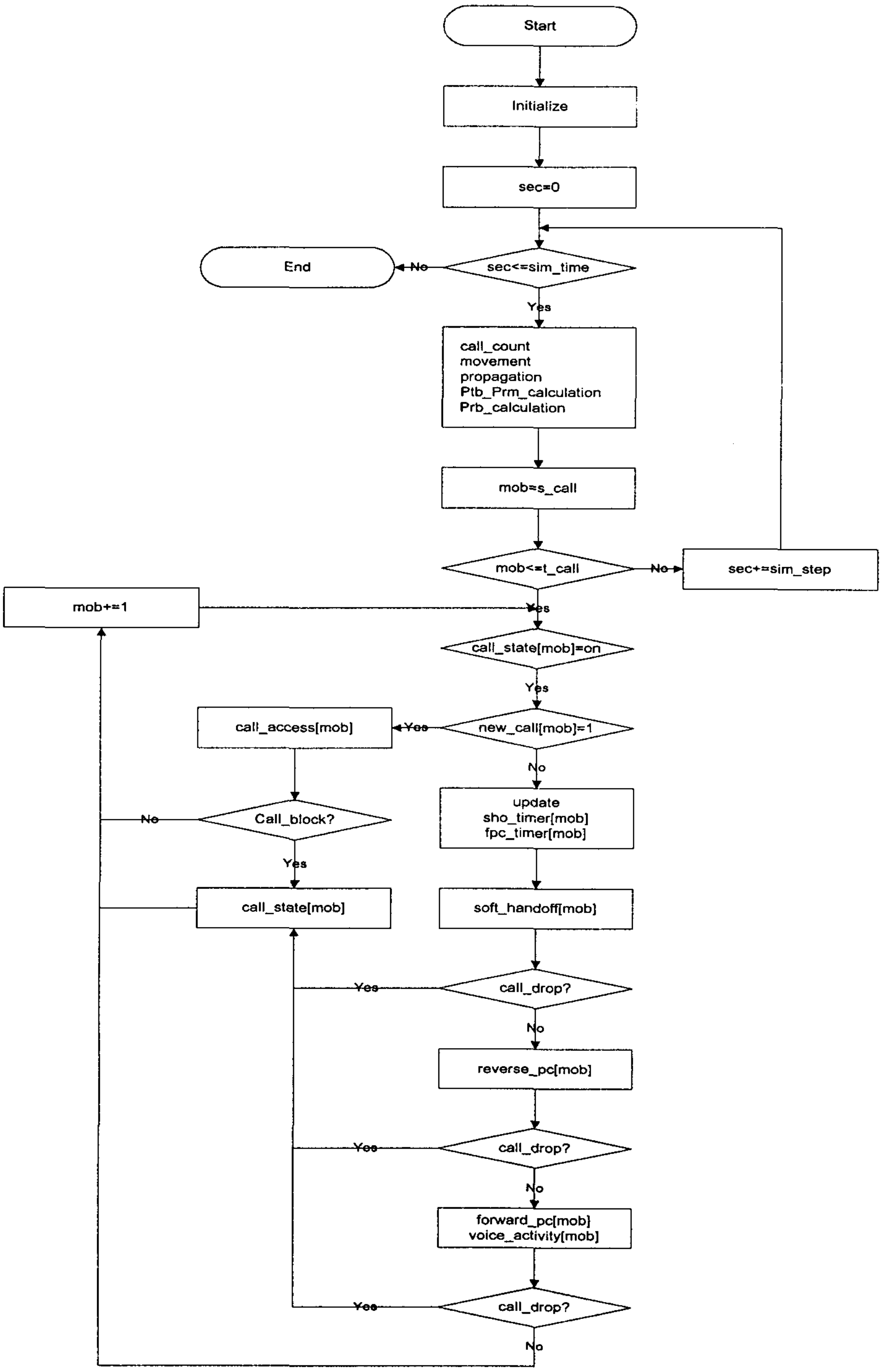
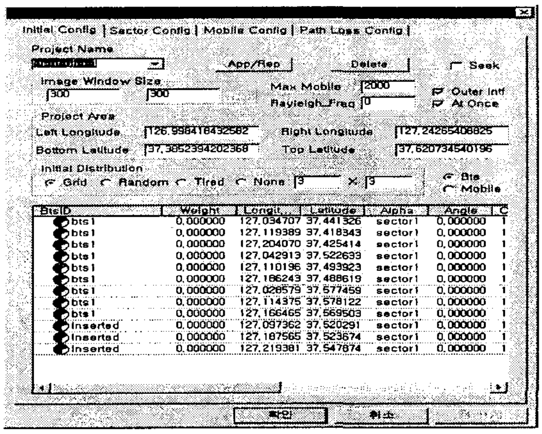


Fig. 10. System level network simulation flow diagram

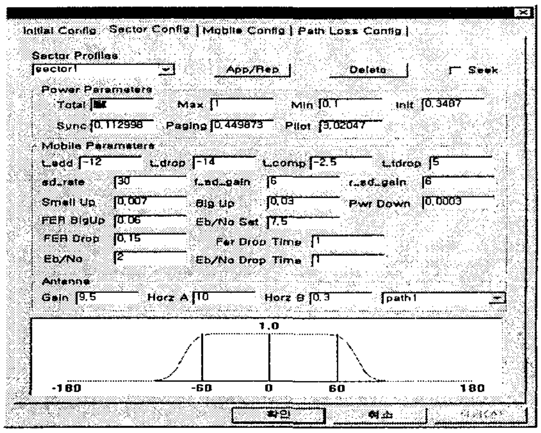
B. Graphic User Interface of System Configuration

In this section of this paper, graphic user interfaces being built in system level simulator, are shown by following figures. This graphic user interfaces are implemented by Microsoft Visual C++ to define simulation environments.

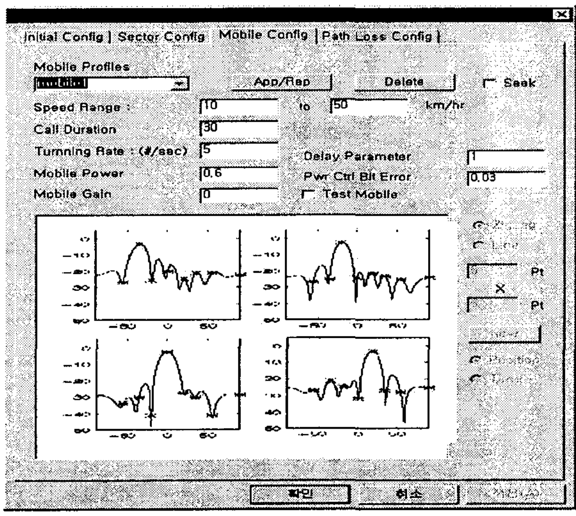
When defining the simulation environment of CDMA network, system configuration, cell configuration, and mobile configuration are used to define each parameter to be entered as simulation environment.



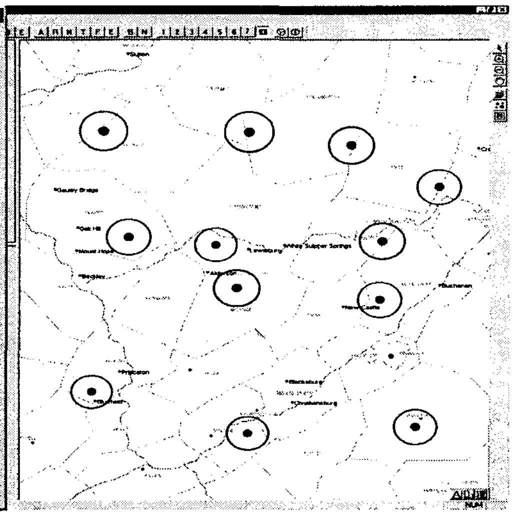
(a) System configuration



(b) Base station configuration



(c) Mobile station configuration



(d) Locating base station on GIS

Fig. 11. Graphic user interface of system configuration

In cell configuration shown as (b) in Fig. 11, user can define radiation beam pattern of antenna, which is applied at base station. The radiation beam pattern is computed by adaptive array algorithm at each simulation snap shot after implementing adaptive array algorithm in network simulator. Simulation environment for mobile station is defined in mobile configuration shown as (c) in Fig. 11. At each simulation snap shot, adaptive array beam pattern for selected mobile is computed with adaptive array algorithm. In system level network simulator has MapX interface to accommodate base station on real mapping location on GIS shown as (d) in Fig. 11. User easily locate base stations on real world map to simulate network performance with SINR based adaptive array antenna with dynamic handoff and power control algorithm.

V. Simulation Examples and Discussion

This section represents simulation examples, that is equi-distance boundary based on base station located on GIS, instantaneous link connection between base station and mobile station, Eb/No distribution of forward/reverse link, and analysis of soft/softer handoff region on bit mapped color display by an example set of simulation parameters.

A. Equal-distance Boundary

In order to calculate initial state of simulation network, equal-distance boundary is very useful to define initial ownership of each call among multi-base stations shown as Fig. 12. Equal-distance boundary is physical reference for calculating initial interference and SINR for each mobile station. Then, exact signal power and SINR for each mobile station are computed from power control and handoff algorithm at each snap shot with mobility and traffic loading. After applying power control and handoff algorithm on each links between mobile and base stations, each mobile station is placed under actual call state by power control and soft/softer handoff.

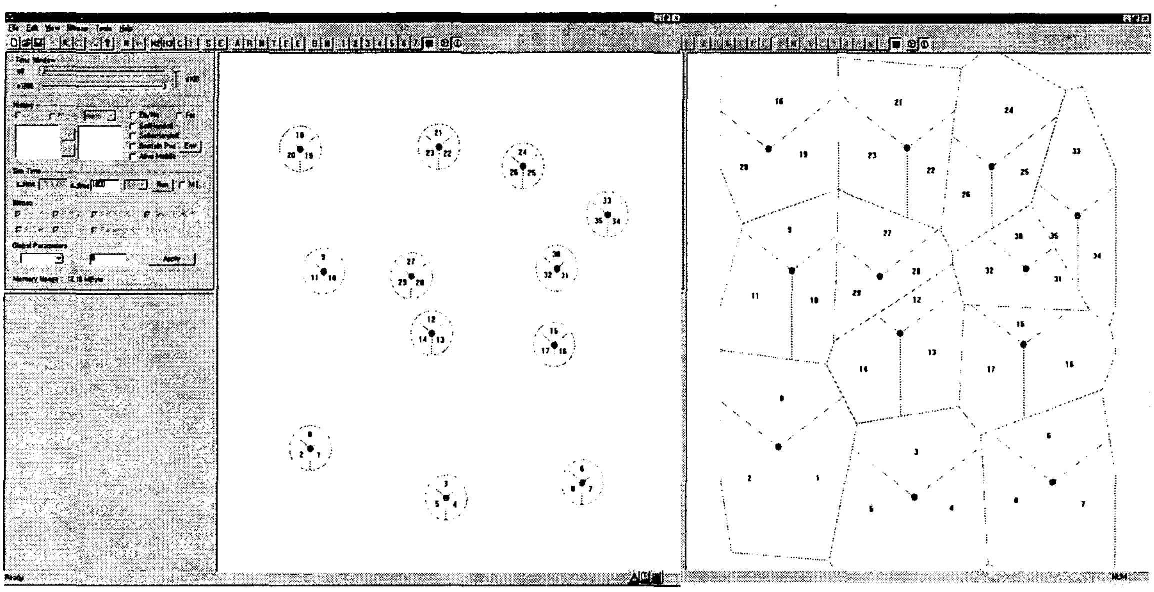


Fig. 12. Equi-distance base station boundary

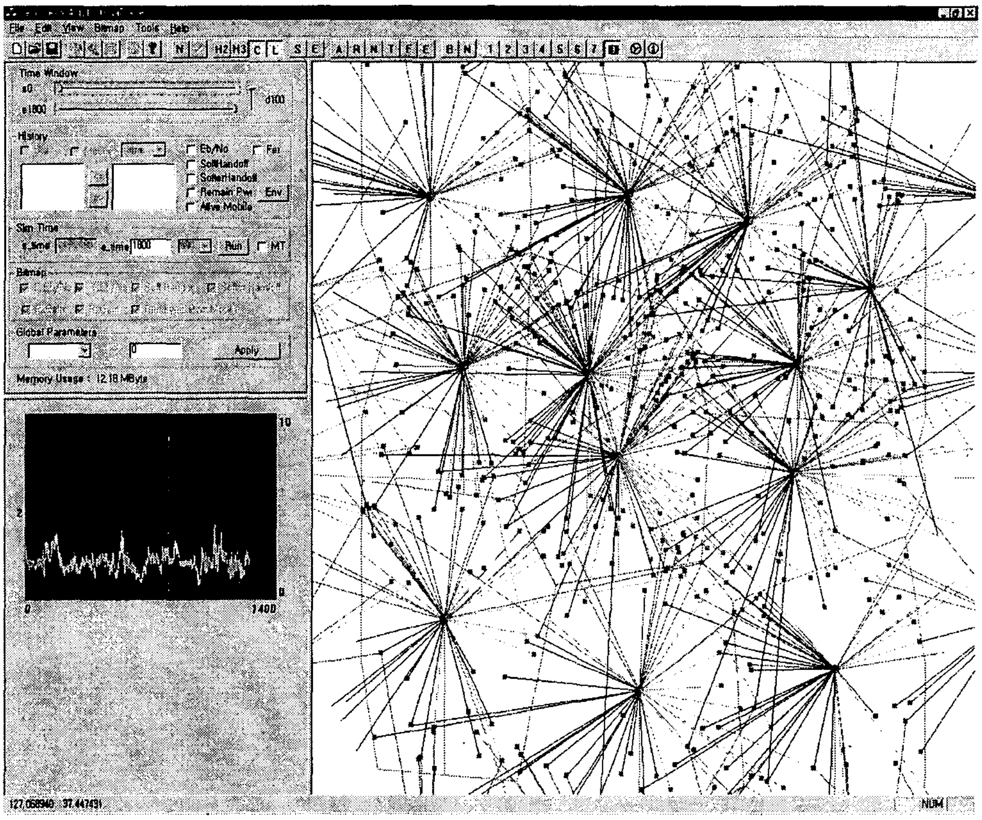


Fig. 13. Link connection between base station and mobile station

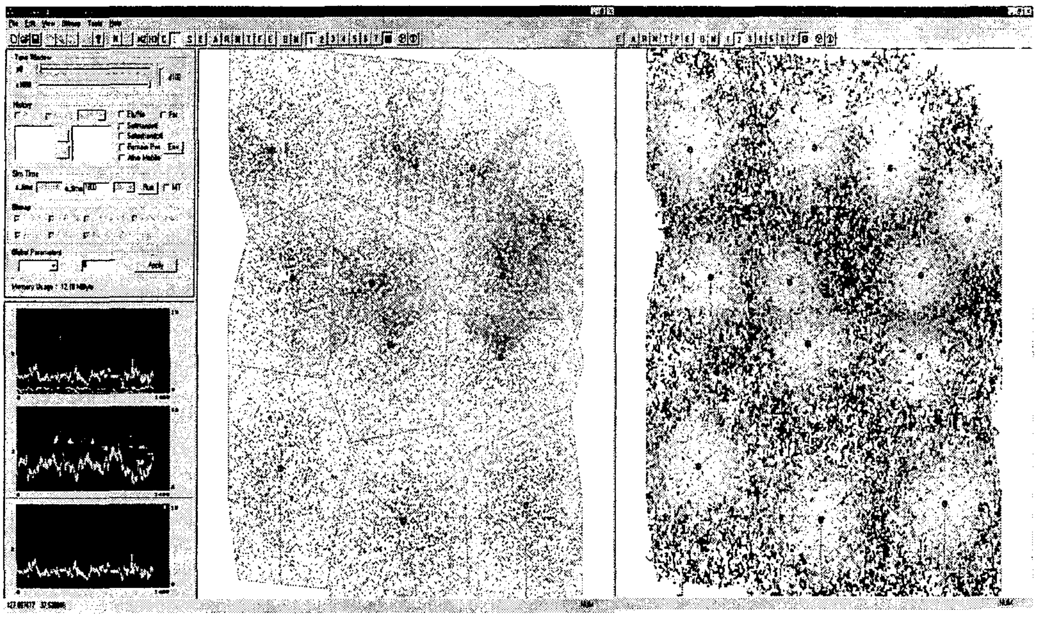
B. Link Connection between BS-MS

During system level network simulation, it is necessary to look at each link between base stations and mobile station shown as Fig. 13. Link connection between BS/sector and MS reflects soft or softer handoff from multiple connections with base stations or with sectors. Three-way handoff is also displayed on this link display window. Its handoff status is stored on each bit mapped mobile location by color code from the number of handoff. Bit mapped color code is displayed on handoff display window to represent handoff region or handoff behavior.

C. Eb/No Distribution at Forward and Reverse link

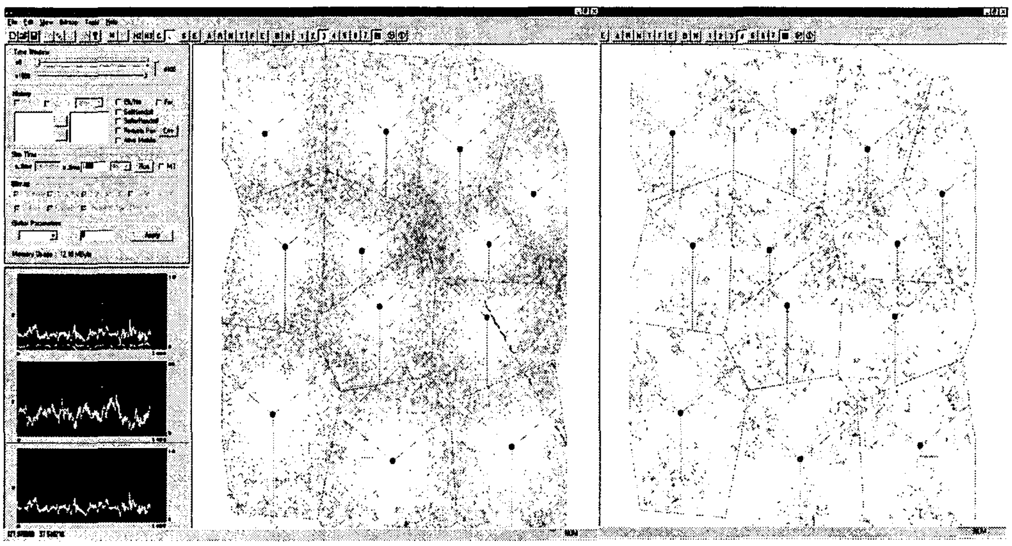
Forward link Eb/No is computed at mobile station by sensing signals from base station with interference environment. Forward link Eb/No display window is useful to investigate the performance of adaptive array for power transmission in spatial domain.

As shown in an example of simulation, reverse Eb/No is generally uniform on area of coverage by power control algorithm of reverse link shown as (a) in Fig. 14. Reverse link Eb/No is computed at base station by sensing signal from mobile station with interference environment under power control and rake combining.



(a) Eb/No distribution at reverse link (b) Eb/No distribution at forward link

Fig. 14. Eb/No distribution at forward and reverse link



(a) Soft handoff region (b) Softer handoff region

Fig. 15. Analysis of soft/softer handoff region

D. Analysis of Soft/Softer Handoff Region

As displayed in Fig. 15, analysis of soft/softer handoff region is representing handoff region computed from handoff algorithm with SINR based power control under radiation beam pattern by adaptive array antenna.

E. Discussion for Examples of Simulation Results

From those simulation examples, Fig. 13 mainly represents the simulation process for tele-traffic model, and mobility model, which is tracked, and updated by simulation snap shot on graphic user interface from initial state represented by Fig. 12. Call connection in Fig. 13 is representing active call modeled by tele-traffic model generated randomly, and mobility model of direction/velocity change defined by simulation environment parameters.

As shown in an example of simulation, reverse Eb/No is generally uniform on area of coverage by power control algorithm of reverse link shown as (a) in Fig. 14. If power control algorithm is not accurate to maintain constant Eb/No at base station, and/or power control step size is not given properly, the network performance is getting worse. As shown in (b) of Fig. 14, forward Eb/No is related on propagation loss at each mobile station. Fig. 14 shows reverse link Eb/No is uniformly distributed by power control compared with forward link Eb/No distribution. It reflects IS-95A/B system is more forward link limited as the cells are located denser as in metropolitan area, even though CDMA system is known as theoretically interference limited by reverse link. It also provides the knowledge that the stronger forward power control may be required for next generation CDMA system.

In the soft and softer handoff simulation, Fig. 15 shows soft and softer hand off region from the beam forming profile of array antenna, in which we put antenna beam forming patterns into simulation platform by off-line calculation of beam patterns. In this simulation of Fig. 15, it is interesting to see that even a few hand-off may be happened in nearly center of BS location caused by fading and log-normal shadowing channel. It is more realistic situation only by system level network simulation.

On the other hands, in order to develop the innovative adaptive beam-forming algorithm to be applied to array antenna, it is necessary to investigate the network performance under its adaptive algorithm whether its algorithm into network architecture represents innovative or not. It is one reason for building the system level network simulation. As shown in examples of simulation results, it is very difficult to take into account adaptive array algorithm by on-line processing because of simulation complexity based on symbol level calculation

VI. Conclusion and Future Work

This section reviews the system level network simulator to consider adaptive array antenna by off-line calculation of beam patterns in CDMA mobile communication system. In system level simulator, network simulation framework is implemented based on IS-95A/B system. Its simulation model, such as vector channel model, adaptive beam forming algorithm, handoff model, and power control model, are described with simulation block diagram. In order to maximize SINR of received signal at antenna, Maximin algorithm is considered, and it is computed by off-line at each simulation snap shot with SINR based power control and handoff algorithm. Graphic user interface in this system level network simulator is also implemented to define the simulation environments and to represent simulation results on real mapping system.

The future work will be implementation and enhancement of simulation framework of IMT-2000 mobile communication system. It will provide insight into investigating dynamic handoff under adaptive array antenna, and into simulating system level network behavior of IMT-2000 with adaptive array. It will also provide deploying strategy of adaptive array beam forming antenna into the overall network by vector channel model in multi-path environment.

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