Development of the Test and Evaluation Systems for the CDMA Mobile System

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CONTENTS

ABSTRACT

In this paper, we present three kinds of development support systems (test and evaluation systems), which are developed to fulfill the specific needs in accordance with the CDMA Mobile System (CMS) developmental phases. The support systems consist of the mobile switch traffic simulator (MSTS), the mobile call simulator (MCS), and the CDMA mobile system analysis tools (CSAT). The MSTS is used for the simulation of the base station in the stage of development of the mobile exchange, and the MCS is used for the overall performance test of the CMS. The CSAT is used for the CMS performance evaluation. These systems have been used for the CMS development successfully.

I. INTRODUCTION

The CDMA Mobile System (CMS), which is based on IS-95 [1], consists of four major elements: mobile exchange (MX), base station (BS), home location register (HLR) and mobile station (MS). Figure 1 shows the simplified block diagram of CMS system and the points at which each test system is connected physically or symbolically.

The mobile exchange differs from the existing PSTN exchange in terms of the interfaces such as the radio link between MS and BS, and the digital trunk between BS and MX. At initial developmental stage of the CMS project, the mobile switching software is tested on the TDX-10 ESS, which is a kind of digital switching system and developed by ETRI. It is recognized then that base station hardware would not likely be available during the early stage of software testing. Therefore, as a part of the exploratory work, a simulator that would be able to simulate the base station environment is designed, where the system is named as the mobile switch traffic simulator (MSTS).

In the middle of the developmental phase, an integration of MS, BS, MX, VRL, and HLR is needed. For the overall end to end functional test and the overload test of the CMS system, the mobile call simulator (MCS) that produces multiple real mobile calls has been used .

While simulations of specific aspects of CDMA system such as the performance of a receiver, power control, handoff are needed for early performance evaluation [7], it is necessary to also evaluate the system performance based on measurement data of the more complete system in a real propagation environment. For this purpose, the CDMA mobile system analysis tools (CSAT) is developed.

This paper is organized as follows. In Sections II and III, the MSTS and MCS are described, respectively. In Section IV, the CSAT and the performance evaluation of CDMA mobile system using the CSAT are presented. The summary is contained in Section V.

II. MOBILE SWITCH TRAFFIC SIMULATOR

The MSTS is designed to simulate base station and generate signaling traffic for the functional test and the load test of the mobile exchange. The MSTS is used to develop and install the mobile exchange. It supports the three following functions:

1) Simulation for the network element: Because mobile exchange is connected to the base station through the digital trunk and the signaling link, the MSTS also must have the T1/E1 digital trunk and EIA-422 signaling link interface capabilities to simulate the network element. It acts like base station and transmits the call connection con-

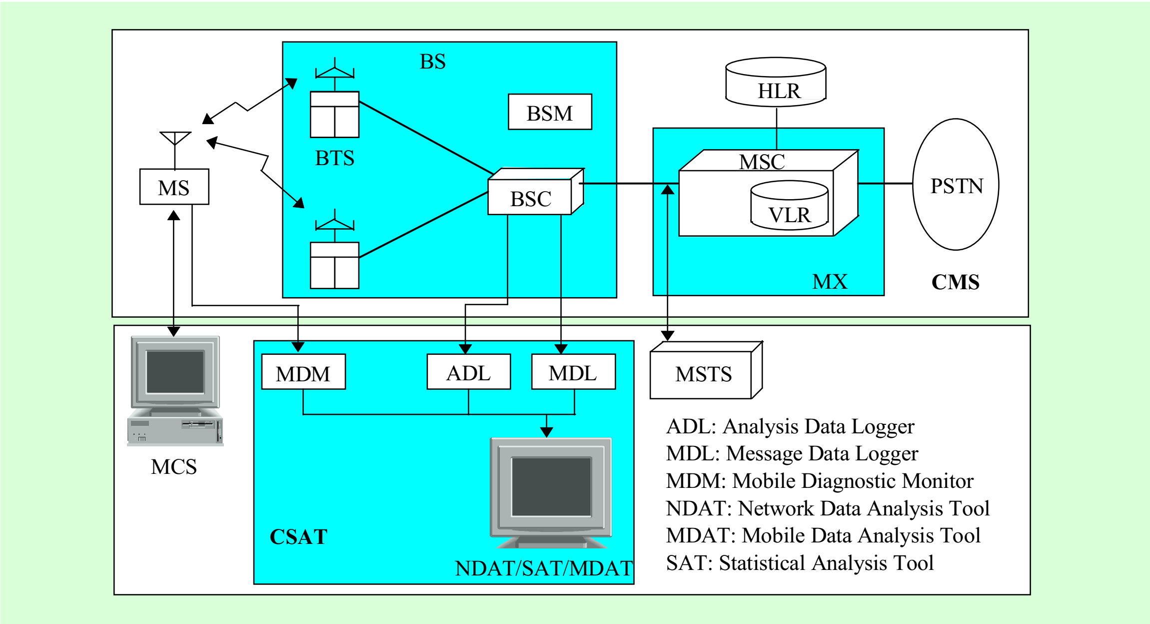

Fig. 1. Configurations of the CMS and the support systems (test and evaluation systems).

trol message and registration message to the mobile exchange.

2) Traffic and load simulation: It can be used in the load test and the long time conformance test to simulate additional situations which is performed with the real traffic between the mobile exchange and the other CMS elements. The traffic is generated about 20,000 calls/hour by the command of operator according to the test scenarios which are stored in the data base of the MSTS.

3) Signaling monitor. This function monitors the signaling messages between the mobile exchange and the base station. The CMS elements use the predefined protocol in call processing. When the protocol mismatches, the call processing fails. And consistencies of the signaling messages should be checked with the recommended interface protocol.

1. Hardware

The MSTS hardware is functionally devided into two modules: traffic channel tester (TCT) and simulator control workstation (SCW) as shown in Fig. 2. The TCT and SCW are built by utilizing the TDX-10 standardized peripheral devices and UNIX based workstation, respectively.

The TCT is used in testing the voice paths. It is composed of the R2 MFC signal transceiver, time switch, trunk interface, and peripheral control processors. The R2 MFC signal transceiver consists of six-

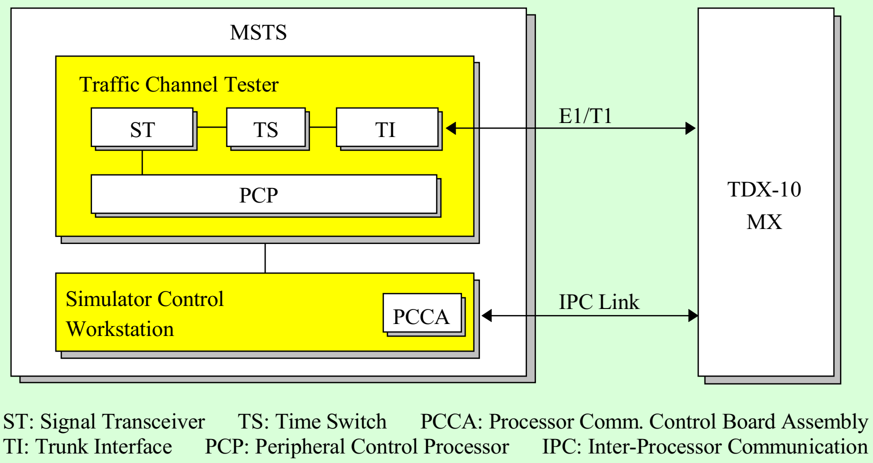

Fig. 2. Mobile switch traffic simulator architecture.

teen channels per one card and is connected to the subhighway in the time switch. Two signal transceivers are used to send and receive test tones continuously in both directions during voice connection on the assigned channels. The trunk interface terminates a set of E1/T1 digital trunks from the mobile exchange. The trunks carry traffic from/to simulated mobile stations.

The peripheral control processor controls peripheral devices by the command of the SCW, and reports the test results via EIA-232 interface that is connected to the SCW. These functions are also used for performance test of the mobile exchange under real traffic conditions.

The SCW hardware consists of a UNIX based workstation and the processor communication control board assembly (PCCA) which is used for signaling link between the mobile exchange and the MSTS. It can be extended up to eight links by VME bus and connected to the inter-processor communication (IPC) node of mobile exchange by IPC-link interface. It is composed of a 32 bit micro-processor, Serial Input/Output controller (SIO) for a high level data link control communication protocol, direct memory access device and first in first out (FIFO) buffer to prevent overrun and underrun of signaling message. The data transmission rate of the signaling messages between the mobile exchange and the workstation is 2 Mbps.

2. Software

To provide extensive testability and the real time multitasking processing environment, the MSTS software has been designed on the UNIX workstation. It is capable of generating about 2000 calls per hour of which load is enough to test representative loads of various calls in the call processing subsystem of MX. The SCM can process many independent test event scenario programs concurrently, and read the user input data and convert them into executable blocks.

To emulate the various functions of the BS, the test scenario files, the message sequence files, and mobile user data are input to the traffic simulator executor (TSE) The test data is hierarchically structured so that operators can easily manipulate the test scenario. The test procedure and results can be monitored simultaneously by the multiwindows.

The setup command in TSE makes it easy to modify or change the configuration of test scenario, the messages sequence, and MS information in each step by selecting the corresponding function on the menu as shown in Fig. 3. During the set-up, information elements are temporally stored in the log file to construct a message or analysis in its sending or receiving state.

The TSE creates a main procedure in terms of event of test scenario. Each main procedure creates sub-procedures in terms of message. Consequently each sub-procedure prepares signaling message using the information elements of the corresponding message and the MS information. This process repeats sequentially according to the events of the test scenario. Table 1 shows an example of the relationship among

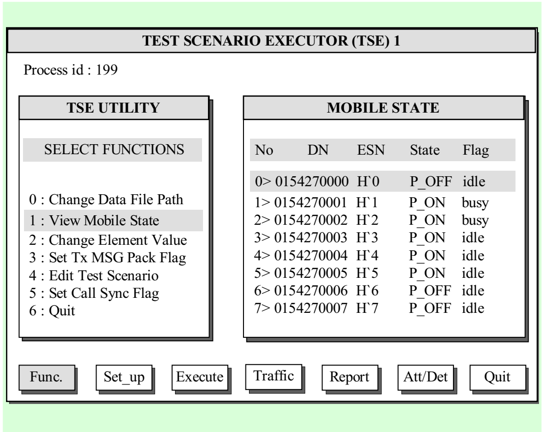

Fig. 3. Test scenario executor.

a test scenario, their events and their messages.

The TSE also supports the functional test and load test for functionality, reliability and performance of call processing software of the MX. The functional test can be performed in the normal mode or in the iteration mode.

The normal mode is to check the basic call processing functions such as the mobile originating and terminating call, the several types of handoff calls, and the location update. In the normal mode, each individual test scenario is executed once and shows the ongoing status of the event and consequent messages. Additionally, in this mode the state and information of the voice channel are monitored. Each test scenario can also be executed repetitively by designating the number of iteration. The abnormal test is also supported by changing the scenario file, the message sequence file, or the

Table 1. The relation between test scenario, message and elements.

Originating call test scenario	
Originating DN	0154280096
Terminating DN	0154280097
Event sequence	1. Power on 2. Dial 3. Delay 4. BS release

Message sequence of dial event				
Sequence	Message name	Direction	Time	Type
1	Setup	Tx	1	M
2	Assignment request	Rx	20	O
3	Assignment complete	Tx	1	O
4	Call proceeding	Rx	20	M
5	Alerting	Rx	20	M
6	Connect	Rx	20	M
7	Connect ack	Tx	1	M

Information elements of setup message			
Element name	Direction	Type	Length
Protocol discriminator	both	MF	1
Message type	both	MF	1
Called party No.	both	MV	4-35
Mobile ID	b2n	MV	7-12
Circuit ID Code	b2n	MF	3
Registration zone ID	b2n	MV	4-8
MS classmark	b2n	MF	4
Cell identifier	b2n	OV	4-9
More digit	b2n	OF	1
Service option	b2n	OF	3

information elements. With the functional test, this abnormal test is necessary for validation of the signaling protocol and call processing software debugging.

The load test is performed by generating the two call groups: the mobile originating call group and terminating call group. The number of test calls and the starting (or terminating) time of each group are specified by the operator. The call duration and the interval between calls are also manipulated by the operator. After the completion of load test, the number of attempted calls, completed calls, failed calls and test periods are reported. It is also possible to access the detailed error information during the test.

The MSTS simulates the BS by utilizing the 'mobile to mobile' calls, because the 'mobile to mobile' calls require more signaling traffic than the 'mobile to land' or the

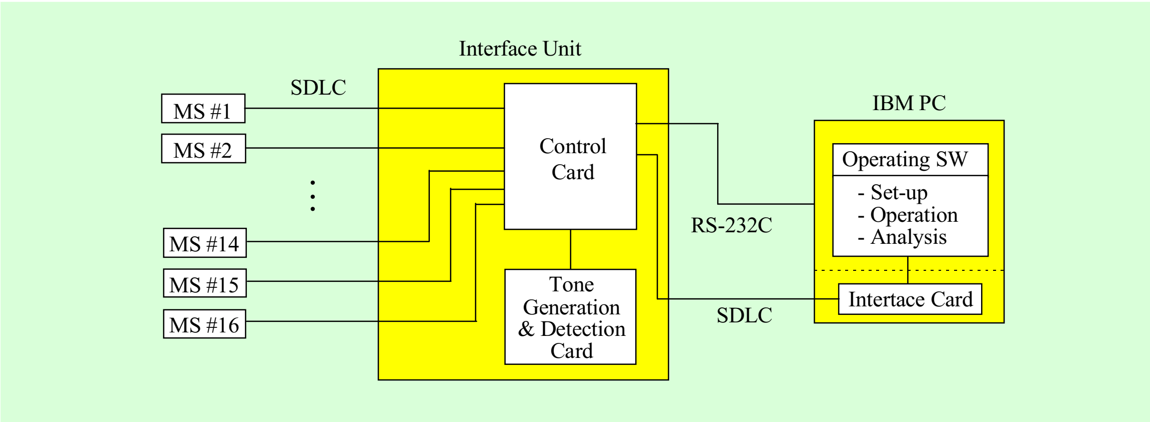

Fig. 4. MCS hardware configuration.

'land to mobile' calls. The load test environment using the 'mobile to mobile' calls is more severe than the real field.

III. MOBILE CALL SIMULATOR

The mobile call simulator (MCS) generates mobile calls and monitors the call results. It can generates up to 16 calls simultaneously. It is implemented on a personal computer which accomodates 16 mobile stations. It confirms the voice signal path using tone generation and detection. It interworks with the PSTN call simulator to generate a mobile to land call. The calling scenarios are fully programmable. It can test call completion rates, mobile error messages, failed call reasons, etc. The data are sufficiently detailed to evaluate call statistics and call processing analysis. It provides the desired monitoring, control, and analysis capabilities through repeated call attempts.

The fully loaded system capacity test requires many mobile calls. For this purpose, making a large number of calls by human is almost impossible because it is hardly possible to monitor the internal status of mobile stations and to obtain the desired timing among large number of calls. The MCS is used to test call completion rates and call processing capability of the base station. The system manufacturers may use it for verifying system requirements and stability. Later on, the operating company use it as a test equipment in the base station setup phase for the commercial service.

1. MCS Hardware

The hardware configuration is shown in Fig. 4. It consists of mobile stations, an IBM compatible PC, and one interface unit. The mobile station is a CDMA mobile phone without any physical modifica-

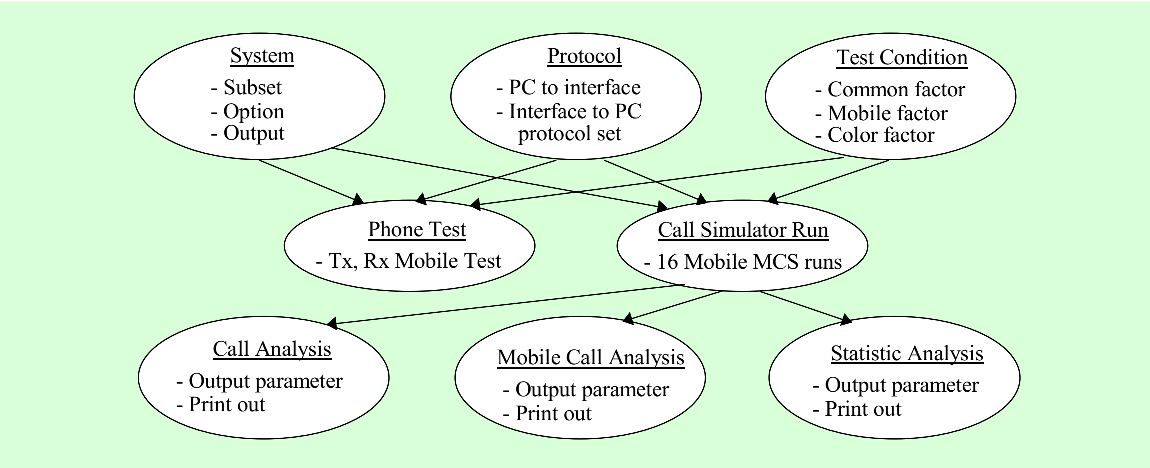

Fig. 5. Configurations of the MCS software.

tion [1].

The interface unit includes two cards: a control card, and a tone generation and detection card. The control card, which is built around an 8 bit micro-controller, handles EIA-232 and SDLC (Synchronous Data Link Control) communications between 16 mobile stations and the PC. The PC controls the control card to select each mobile station's communication path using EIA-232. The PC gathers the mobile station internal status information using the SDLC protocol.

The tone generation and detection card generates and detects multiple tones to verify the voice path quality and signaling tone after the traffic channel is assigned to the desired mobile station. It is made of a 16 bit DSP microprocessor. It is divided into the tone generation section and the detection section. The tone generation section generates multiple digital tones and transmits them as analog tones via 8 bit D/A converters. The tone detection section converts the received analog tone signal into the 10 bit digital data with 8 KHz sampling rate. The converted data are translated into frequency domain using 256 point fast fourier transform before detection.

2. MCS Software

The MCS software, as shown in Fig. 5, contains a test condition module, a mobile station test module, a call simulator run module, and a call analysis module. The test condition module defines test conditions of the mobile calls. It includes test time, the number of test calls, and call types (voice, recorded voice, single tone, multi-tone). It also defines each mobile station's modes (call origination or call termination, called number, and call attempt parameters (call duration time, idle time). The phone test module tests each mobile's status. It checks the status of each mobile station operation.

The call simulator run module is the main part of the MCS software. It controls all of the 16 mobiles and manages the calling scenarios. It gathers the results of the real-time call statistics and displays the current results (number of call attempts, successful calls, failed calls, and call failed reason). It has six states as shown in Fig. 6. The MCS enters the paging and ringing state during the interval between sending a call origination message and receiving a ringback tone. In this state, if the base station cannot process the call setup, the mobile station decides this call as a failed call. The traffic state starts after receiving a ringback tone. This state controls the traffic duration time. In the traffic duration, the state checks a received power level (dBm), FER, and the traffic channel code number. The actual call type is defined as voice, recorded voice, single tone, and multi-tone according to the test condition. In the tone sending call type, a single or multi-tone is sent to the opposite mobile station or PSTN test equipment sequentially with the pre-defined frequency and the signal level. Then, the received tone is tested and analyzed to check voice path quality. The release state begins after sending the call release message to the mobile. After the call release, the mobile station remains in the idle state until a new call origination starts. The error state is the exceptional state to check abnormal status of the mobile.

The saved data from the simulator run module are analyzed in the analysis module. The analysis module analyzes test results according to the call completion rates, mobile error messages analysis, failed call reasons, etc. The data allow further analysis for call statistics and call processing in the capacity test.

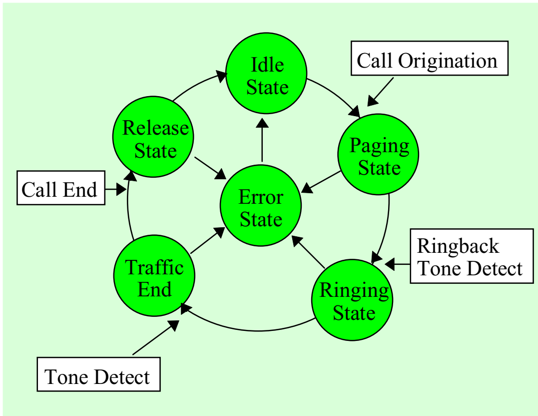

Fig. 6. State diagram of MCS operating mode.

IV. CDMA MOBILE SYSTEM ANALYSIS TOOLS

The CDMA mobile system analysis tools (CSAT) is developed to optimize the network parameters, which affect the power control, soft handoff, and system capacity. The CSAT gathers and analyzes the forward and reverse link data and system messages. For gathering the data and messages, we followed a recommended service option called the mobile loopback call [2]. The collecting devices gathers such data and messages by interfacing with the base station controller and the mobile station as shown in Fig. 1 and Fig. 7.

The analysis is aimed at evaluating the CDMA network performance for both forward and reverse links in terms of the power control, handoff threshold, and forward and reverse link parameters. The performance measures for the reverse link are the cell received E_b/N_o, the reverse frame error rate, the required mobile transmit power to reach the reverse link E_b/N_o target, etc. The performance measures for the forward link include softer/soft handoff statistics, the received pilot E_c/I_o at the mobile, and the allocated forward traffic channel power.

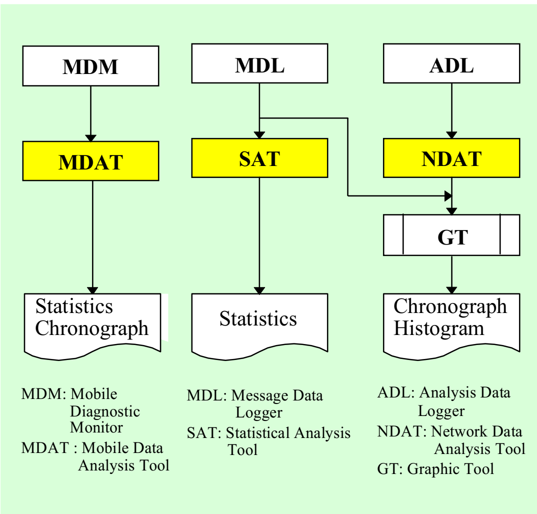

Fig. 7. Configurations of the CSAT.

In the following subsections, we discuss the CSAT configurations, data logging procedures, the performance analysis tools, and the CSAT applications in detail.

1. CSAT Configurations

The CSAT consists of the logging devices and the performance analysis tools as shown in Fig. 8. The logging devices are the analysis data logger (ADL), the message & data logger (MDL), and the mobile diagnostic monitor (MDM). The performance analysis tools are the network data analysis tool (NDAT), statistical analysis tool (SAT), and the mobile data analysis tool (MDAT).

The logging devices are implemented using IBM compatible personal computers. The ADL and MDL equip with the protocol analyzer and tester (PAST) board. Interfaced with the BSC through the HDLC protocol, the ADL gathers the forward and reverse link data, and the MDL collects the system messages, respectively. The mobile diagnostic monitor (MDM) interfaces with the mobile station through the HDLC protocol, and collects the forward link data, and mobile station's position which is supplied by the collocated global positioning system (GPS) receiver installed at the test vechicle.

We implemented two kinds of software version of the NDAT, which operates on a SUN-Sparc workstation with Openwindows and a personal computer. The SAT runs on a SUN-Sparc workstation, and the MDAT operates on an IBM-compatible personal compu-ter with Window NT. The NDAT analyzes the radio link performance such as the frame error rate, cell received E_b/N_o of forward/reverse link, and the reverse link

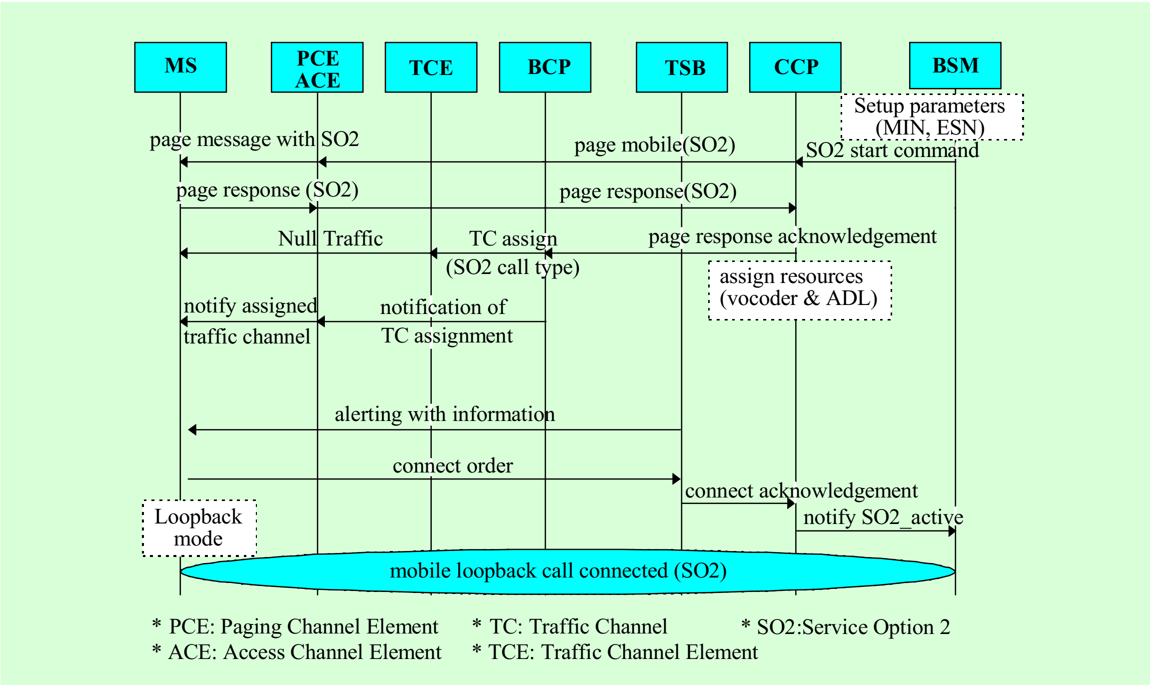

Fig. 8. Mobile loopback test call procedures.

power control error, etc. The SAT provides traffic statistics regarding softer/soft/hard handoff such as number of handoff and handoff duration per mobile station, and handoff statistics per cell. The MDAT provides bin maps related to the handoff, mobile receive/transmit power, etc.

2. Data Logging Procedures

The test calls are generated to reflect the realistic transmission data rate, and the voice activity factor. The data rate and the corresponding voice activity factors considered are 9600 bps and 0.29, 4800 bps and 0.04, 2400 bps and 0.08, and 1200 bps and 0.59. In the mobile loopback call test, the test call is generated by the base station manager (BSM). The MS, after receiving the forward link data frame, sends back to the transcoder and selector bank (TSB) the test call data with the foward link status [2].

Figure 8 shows the mobile loopback test call procedures. The base station manager (BSM) sets up and releases the test call as well as monitoring of the call status, and the TSB generates the forward link traffic data frame. In addition, The TSB can generate only full-rate data for initial system parameter calibration.

Mobile station checks the forward link traffic frame received from the TSB through the forward traffic channel element (TCE), and returns the received frame with the forward *cat_type* [2] to the TSB through the reverse TCE. The *cat_type* indicates the checked results on the forward traffic frame status and its transmission rate. After the mobile loopback call is established, the TCE transmits the reverse traffic frame with the log data, which is saved into the ADL through the TSB. The log data of the reverse TCE is as follows: data burst randomizer (DBR) bits, finger's lock status and its energy for each receive antenna and sector, reverse link closed loop power control bits, receive rate of reverse link traffic frame, and the system time.

As the TSB receives the reverse traffic frame from the TCE, the TSB attaches the received traffic frame with the data, and it transmit to the ADL at every 20 msec: outer loop power control threshold (E_b/N_o set point value), reverse link power control subchannel gain, allocated forward traffic channel gain, reverse link *cat_type*, where the TSB decides this parameter based on the forward *cat_type* as well as the reverse traffic frame rate and quality, the selection data and the system time.

With respect to the system parameter and messages, the TCE and the TSB transmit the parameters and messages with a specific packet format to the MDL, such as common air- interface related messages, call processing related messages, and the system time.

The MDM gathers the forward link related data and test environment related parameters, such as mobile transmit/receive power, forward/reverse link traffic frame, mobile station's finger and searcher data, mobile station's position and speed information received from GPS receiver and test vehicle, respectively.

In addition, each logging device collects a mobile station's electrical serial number (ESN), test time, test run number, and the test route, etc.

3. Performance Analysis Tools

The performance analysis tools were developed to analyze and evaluate the CDMA network for both forward and reverse links using the collected data. They consist of network data analysis tool (NDAT), statistical analysis tool (SAT), and mobile data analysis tool (MDAT), respectively as shown in Figs. 9-11.

A. Network Data Analysis Tool

Figure 9 shows the functional block diagram of the network data analysis tool (NDAT). The NDAT analyzes the collected data stored in the ADL to evaluate the radio link performance of the CDMA mobile network. The analysis results are represented as chronographs and histograms through the graphic tool (GT).

The performance parameters evaluated are as follows: the frame error rate regarding reverse and forward link frame quality, burst error length, the received E_b/N_o of the reverse link and outer loop power control threshold, finger energy and number of fingers locked regarding the RAKE receiver,

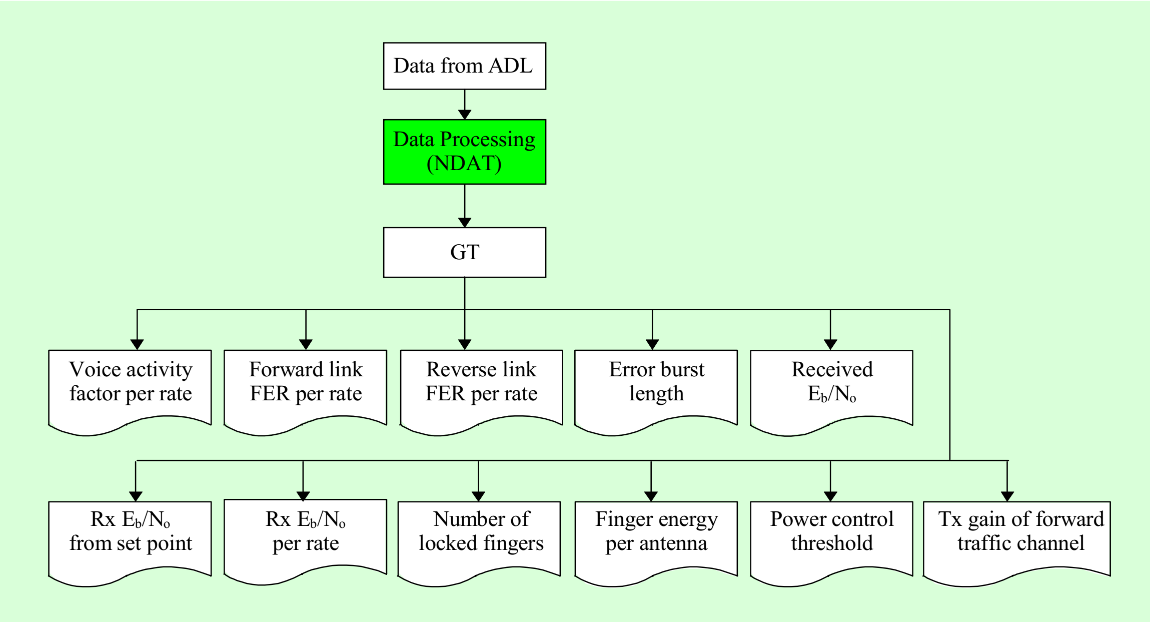

Fig. 9. Funtional block diagram of the NDAT.

and transmit gain of forward traffic channel related to the forward link power control.

1) *Frame Error Rate*

The frame error rate (FER) determines the quality of voice and data, and is used as the reference parameter for the outer loop power control and forward link power control. The FER is calculated by counting the number of bad frames to the total received traffic frames. The procedure for determining bad frames is beyond the scope of this paper and detailed in reference [2].

2) *Error Burst Length*

The error burst length, which is defined as the number of consecutive frames with error, is related to the fading rate, channel coding including interleaving scheme, and power control algorithm, etc.. The mobile station and base station release the progressing call when the consecutive corrupted frame exceeds the predefined threshold number. Thus it is another performance measure of the frame quality together with the FER.

3) *Finger Energy*

The base station receiver has four demodulators for RAKE combining of multipath signals. Two demodulators are configured per antenna. Each demodulator has also two searchers and a finger. The searchers are responsible for initial acquisition of the received signal, and the finger is responsible for phase tracking and data demodulation.

The finger energy is the path gain of the multipath signal. The finger energy

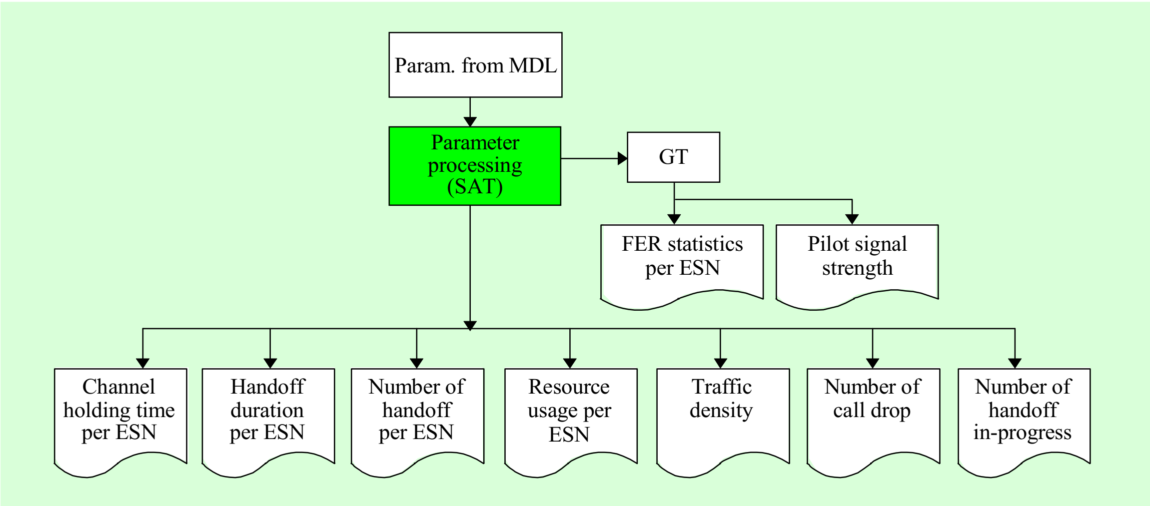

Fig. 10. Funtional block diagram of the SAT.

and the the number of locked fingers can be used for evaluation of the path diversity. In the reverse link traffic channel, the finger energy is mapped to the received E_b/N_o value, and is also used to calculate the average received E_b/N_o per frame.

4) *Number of Locked Fingers*

Each finger of the cell receiver indicates the lock status when the received signal of a path exceeds a specific threshold value. Therefore, from the number of locked fingers, the multipath propagation environment can be estimated. During the field test, we observed, in average, one finger was locked in the indoor propagation environment and four fingers were locked in the outdoor. From this observation we can find that the RAKE receiver is more effective in the outdoor environment than indoor, since the multipath time delay spread is more shorter in indoor environment.

The multipath time delay spread may also be estimated by examining the difference between the earliest arriving and latest arriving demodulator fingers only when the fingers were assigned to a single pilot, since different pilots while in handoff appears as different time offsets.

5) *Average Rx* E_b/N_o

To compute average Rx E_b/N_o, the received finger energy is defined as averaged over the length of the voice traffic frame. A voice frame is devided into 16 power control groups–one power control group is 1.25 ms length. The mobile station transmits the information at different power control group (PCG) assigned by the data burst randomizer (DBR) algorithm [1]. The DBR bits collected in the ADL indicate the position of the information transmitted by the mobile station. The cell receiver has two antennas for diversity. Thus, the average received E_b/N_o is acquired as $T_e/2T_p$, where Te is the sum of the locked finger energy (dB) of "TX_ON" PCG for 4 fingers and 16 PCG, and Tp denotes the total number of power control groups indicating "TX_ON".

6) *Deviation of the Rx E_b/N_o from Set Point*
The deviation of the cell received E_b/N_o from the set point is the closed loop power control error, which affects the system performance as well as the system capacity. $P_{err} = E_b/N_o$ *setpoint* $-$ *received* E_b/N_o, where P_{err} denotes the closed power control error.

B. Statistical Analysis Tool

Figure 10 shows the functional block diagram of the statistical analysis tool (SAT). The SAT is used to analyze the traffic statistics of the CDMA mobile network. With the collected system parameters and messages, the SAT can evaluate the traffic statistics per MS and per cell, such as softer/soft/hard handoff duration, number of handoffs and call duration per mobile station.

For each cell, this tool evaluates the traffic density, number of call drops, and the number of handoff-in-progress during the specific time interval. In addition, the SAT also provides the system resource usage and mobile station measured parameters such as pilot signal strength and the forward link FER during its call duration.

1) *Handoff Statistics per Mobile Station*
Mobile station can experience three kinds of handoffs; idle handoff, soft (softer) handoff between cells (sectors), and hard handoff such as intra-hard handoff between different frequencies within a cell, and inter hard handoff between different frequencies to another cell. The idle handoff is not considered in the SAT since this handoff is not related to the system resource usage of the CDMA network.

2) *Handoff Duration*
Handoff duration is one of the important performance measures in the handoff. The soft (softer) handoff duration is the time interval between the neighbor cell's pilot signal addition and the home cell's pilot signal drop. The overall handoff duration is the sum of all handoff duration occurred during the call.

3) *Handoff Statistics per Cell*
The handoff statistics per cell represents the traffic density, the number of call drops, and the number of handoff-in-progress during the specific time interval for each cell. In addition, the number of handoff occurrence for each cells also used for the optimization of the handoff parameters in a given radio environment.

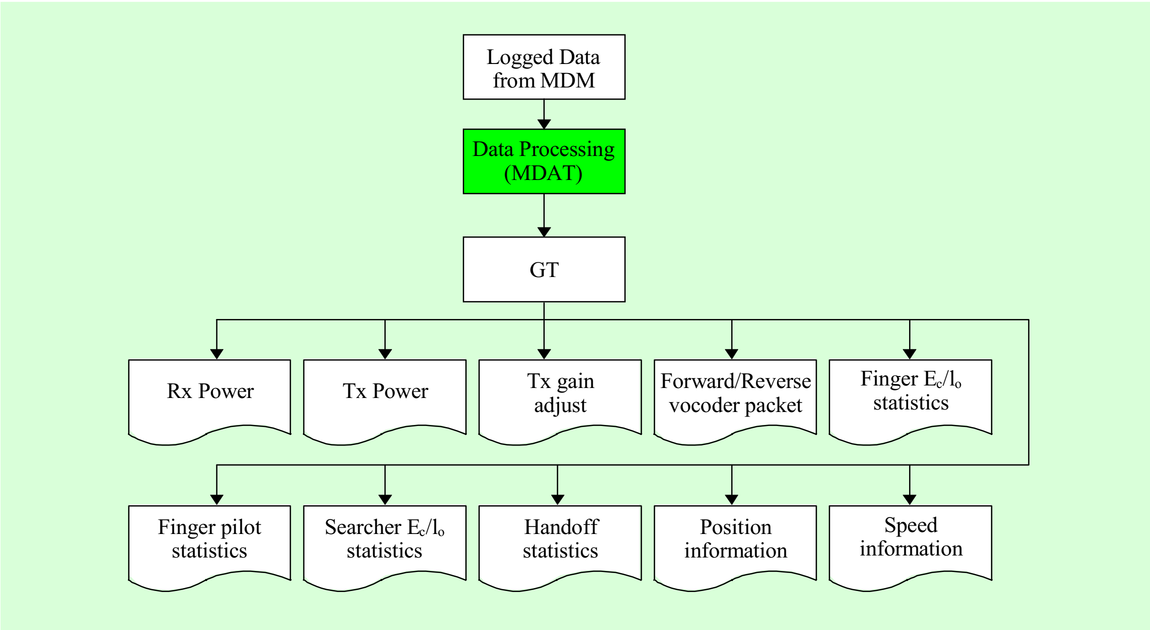

Fig. 11. Functional block diagram of MDAT.

C. Mobile Data Analysis Tool

Figure 11 shows the functional block diagram of the mobile data analysis tool (MDAT). The MDAT analyzes the collected data stored in the MDM to evaluate the forward link performance of the CDMA mobile network. The analysis results are represented as chronographs and histograms through the graphic tool (GT). The performance parameters evaluated are as follows: the mobile received pilot E_c/I_o, the mobile transmitted gain adjusted value related to the performance of open/closed loop power control, the mobile received and transmitted power, and mobile station's position and speed information, etc.

1) *Finger* E_c/I_o

The forward link coverage of the CDMA mobile network depends on the received pilot signal strength (E_c/I_o) at the mobile station. The E_c/I_o is the estimation value of the received pilot power to the total received power ratio. This value is measured only over the locked demodulator fingers.

2) *Tx Gain Adjust*

The mobile station's transmit gain adjust represents the dynamics of closed loop power control. The basic reverse link power control rule is as follows [1];

$$\text{TX Power (dBm)} = -73 - \text{RX Power (dBm)}$$

+ NOM_PWR (dB)

+ INIT_PWR (dB)

+ the sum of all access probe corrections (dB)

+ the sum of all closed loop power control corrections (dB)

The first three terms make up the "open-loop" portion of power control. The RX power is measured by the mobile to estimate the transmit power. The forth and fifth terms are correction to mobile transmit power during access probing. The final term is the "closed-loop" portion of the reverse link power control

3) *Rx/Tx Power*
The Rx power is the mobile received total power, and the Tx power represents the mobile transmit power at the time.

4) *Position/Speed Information*
The mobile station's position and speed information is gathered from the GPS, and is used for producing the bin map, such as handoff, the forward link frame error, and the mobile receive/transmit power over the mobile trajectories. Especially the handoff bin map, which indicates the region of various soft and softer handoff states, can be used for base station deployment.

4. CSAT Applications

In this section we present an example that illustrates the application of the CSAT. We gathered the field data of the CMS, which is configured as two cells having single sector. The number of mobile stations operating as the mobile loopback call were 32, but the data from only 8 mobile stations were collected in the ADL, MDL, and MDM. Since the collecting data are too bulky during the test, the remaining mobile stations were used just for the loopback call, where the data are not gathered. But there are no problems for the system performance evaluation, because the interference effects of the remaining 24 mobiles are considered.

The evaluated results may be used for radio link budget evaluation and network parameter calibration for successful network deployment, but the method is beyond the scope of this paper.

A. Evaluation of Reverse Link Power Control

1) *Open Loop Power Control*
The objective of open loop power control is to compensate the mean path loss variations and shadow fading, and the mobile station adjust its transmit power level downward or upward and thus prevent the mobile station transmitter power from being at too high or low level. After the mobile station measures the power level of both the pilot signal from the cell site to which it is connected and the sum of all the cell site signals, it adjust its own transmitter power: the stronger the received signal, the lower the mobile station's transmit power. Figure 12 shows the transmit gain adjustment value of the mobile station according to the reverse link power

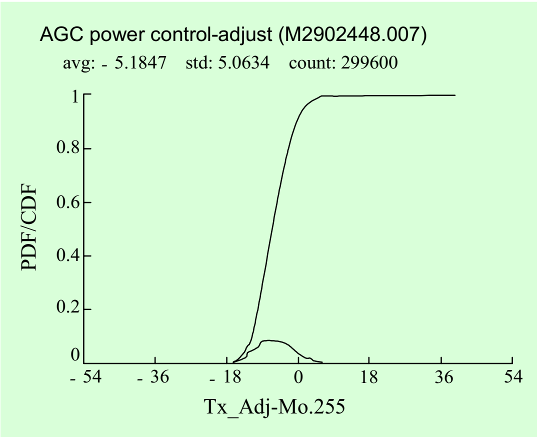

Fig. 12. Tx gain_adj (PDF/CDF).

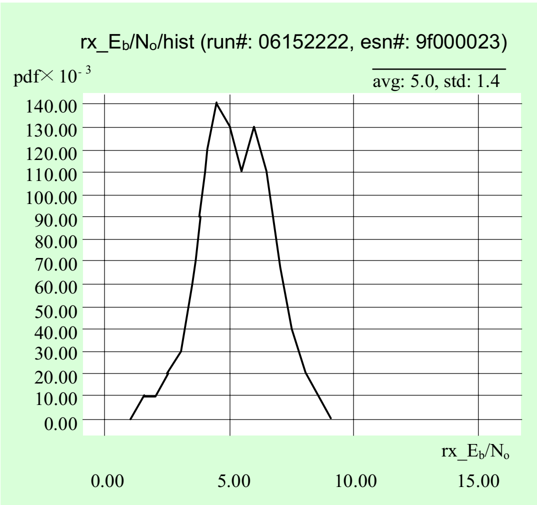

Fig. 13. Cell receive E_b/N_o.

control rule as described in previous section.

2) *Closed Loop Power Control*

The purpose of the closed loop power control is to compensate for asymetries in forward and reverse links. This power control scheme provides mobile stations with the power "up/down" command

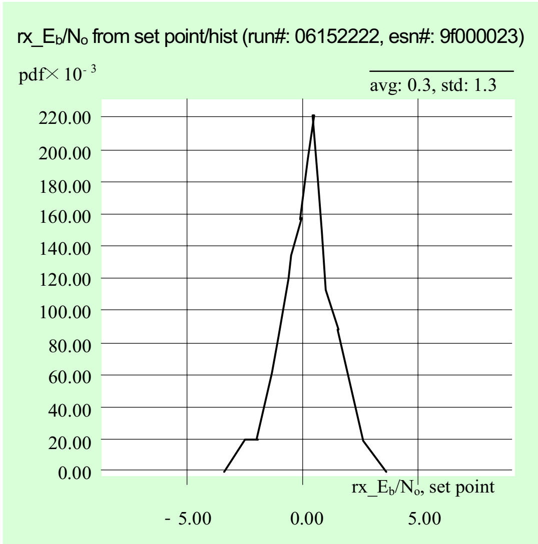

Fig. 14. Cell received E_b/N_o from setpoint.

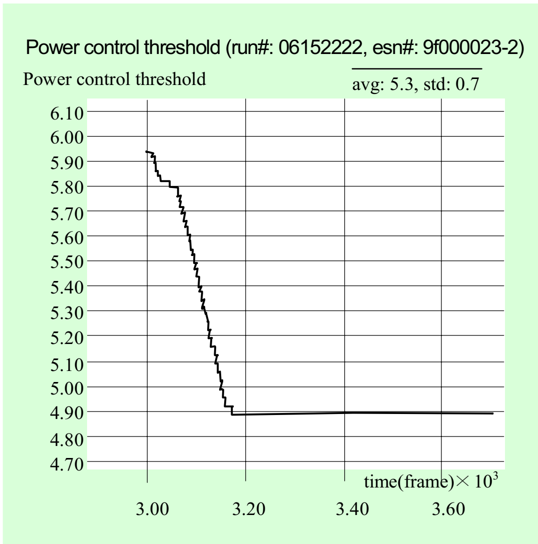

Fig. 15. Power control threshold variations.

at every power control group (per 1.25 ms), which is based on the locked finger energy and power control threshold (E_b/N_o set point). The power control

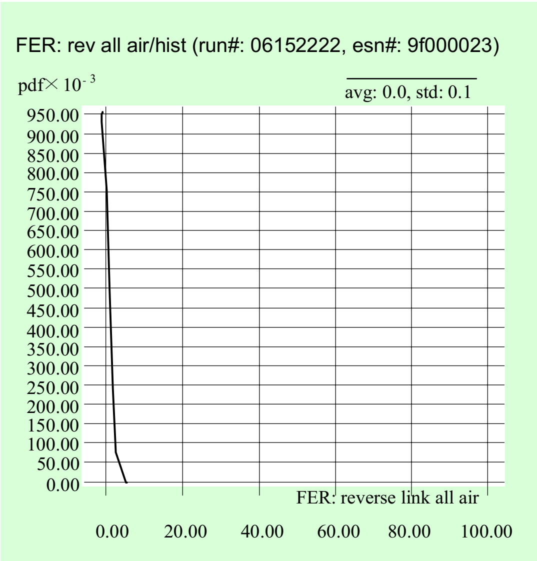

Fig. 16. Reverse link all rate FER.

threshold value is changed according to the outer loop power control rule. Figure 13 shows the cell receive average E_b/N_o for a mobile station is 5 dB. From Fig. 14 we can observe the power control error is almost 1dB.

3) *Outer Loop Power Control*

The objective of the outer loop power control, which is operated at every frame (per 20 msec), is to maintain the frame quality (FER) below or equal to a specific value (e.g. 1 %). The operation of this power control scheme is to change the E_b/N_o set point (as shown in Fig. 15) at every frame (20 msec) which is based on the reverse link frame error rate (Fig. 16). Therefore, the analyses of the power control threshold variations and the reverse link frame error rate are needed to evaluate the outer loop power control scheme.

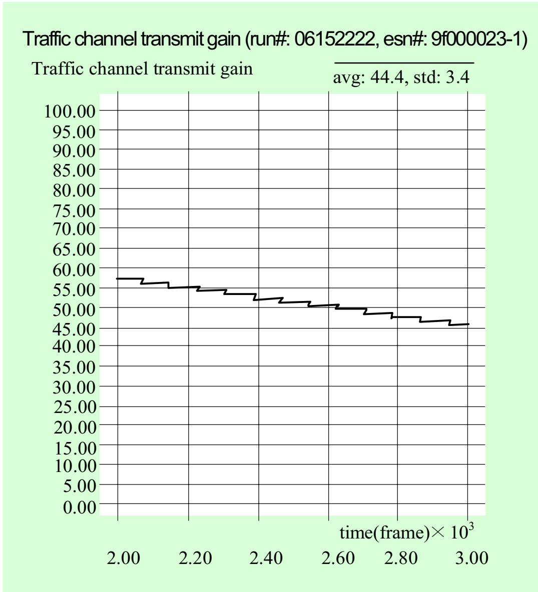

Fig. 17. Forward traffic channel gain and its variations.

B. Evaluation of Forward Link Power Control

The objective of forward link power control is to overcome the "edge-problem". In a nearby cell boundary, the total interference received by the mobile station is increased at a point relatively close to its cell site. Base station controls its forward transmit traffic channel gain according to the forward link frame error rate, which is reported by means of the periodic report and (or) threshold report of the mobile station. Figure 17 shows the allocated forward traffic channel gain based on the forward link frame error rate, and Fig. 18 shows the probability density function of forward link FER for all transmission rate. The nominal gain value is between 43 and 96.

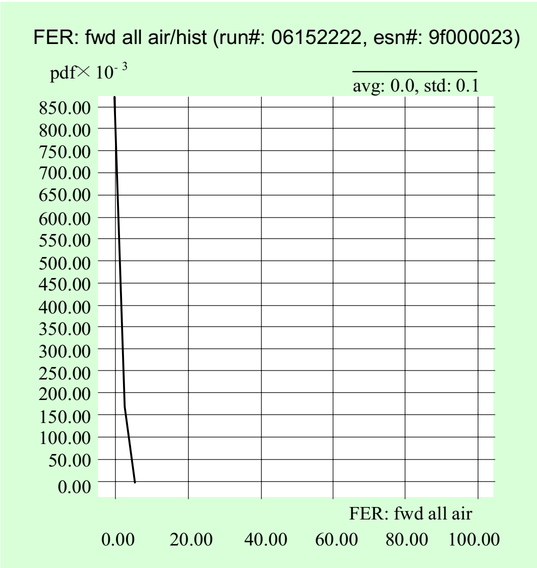

Fig. 18. Forward all rate FER.

V. SUMMARY

The CMS test and evaluation systems consist of three major systems: the MSTS, MCS, and the CSAT. These systems have been designed and implemented to fulfill specific needs, either for the individual CMS subsystem or for the entire CMS systems. The MSTS is used for the simulation of the base station of the mobile exchange, the MCS is used for the CMS load test. The CSAT is performance evaluation tool for the CMS. These systems have been used for the successfuly development of the CMS. They all share the common goal to ensure that the CMS meets its design requirements and provides a high quality of mobile service to the public.

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