Development of Mobile Station in the CDMA Mobile System

Sunyoung Kim, Yoon Uh, Hye-yeoun Kweon, and Hyuckjae Lee

CONTENTS

ABSTRACT

This paper describes the development of the CDMA mobile station to support non-speech, mobile office services such as data, fax, and short message service in addition to voice. We developed some important functions of layer 2 and layer 3. To provide non-speech services, we developed a terminal adapter and user interface software. The description of development process, software architecture and external interfaces required to provide such services is given. The description of a TTA-62 message analysis tool, a mobile station monitoring software, and an automatic test system developed for integration tests and performance measurements is also given.

I. INTRODUCTION

The CDMA mobile station (MS) described in this paper is secure and compact, and offers various services of high guality. This is attributed to rapid advancement in the mobile communications and semiconductor technology. The spread spectrum technique we employed in our system gives high capacity, good voice quality, security, and now provides data, fax, and short message service (SMS) services. The MS becomes a part of everyday life and its application is ever increasing. In order to meet potentially high demands, ETRI and designated manufacturers have undertaken initiatives to research and develop MSs, as a part of the program known as the CDMA Mobile System (CMS).

In the development of our MS, we focused our activities in the following areas :

- Implementation of MS software (SW)
- Development of non-speech services
- Development of a test system and analysis tools
- Evaluation of test results and performance analysis.

This paper presents the development and performance analysis of the MS. The basic architecture and operation of a mobile station are discussed in Section II. The SW development, analysis, design and implementation techniques employed are discussed in Section III. The implementation of data, G3 fax, and SMS services are analyzed in Section IV. Performance evaluation and test systems are discussed in Section V. The test systems include the developed mobile station test, TTA-62 message analysis tool (TMAT) and mobile station monitoring software (MSMS). Future evolution and research areas are discussed in Section VI. Finally, the conclusion is given in Section VII.

II. STRUCTURE OF THE MOBILE STATION

The MS is mainly composed of two hardware modules; digital subsystem and RF subsystem, as shown in Fig. 1. We first describe the MS features, then present briefly its HW structure and operation. Specifications and features of the first generation portable MS are summarized in Table 1.

1. Digital Subsystem

As shown in Fig. 1, the digital subsystem consists of a CPU, memory, a vocoder, a chip set for CDMA baseband signal processing, and a chip set for FM baseband signal processing. 80C186EA processor with 12 MHz speed as a CPU, SRAM, flash memory, and EEPROM for ESN and MIN are major components employed.

On the transmit side, voice is first digitized by the codec, and then compressed by the vocoder to the 8.55 kbps rate with 20 ms frame length. After being added with frame quality indication (FQI) to be-

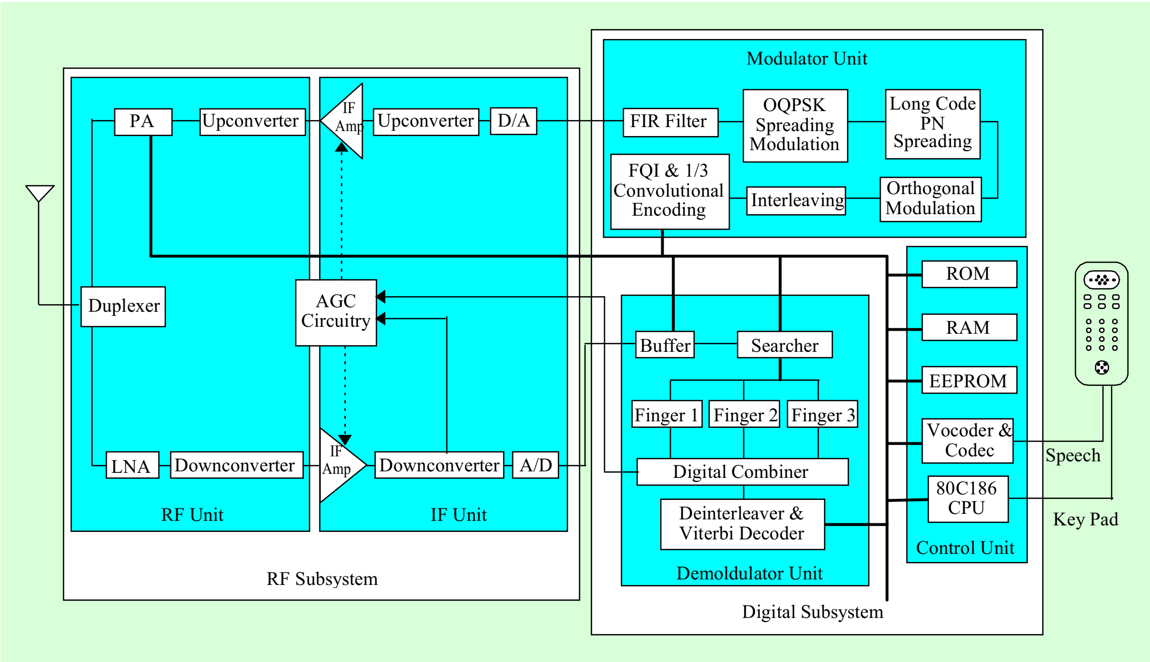

Fig. 1. Structure of CDMA MS.

come 9.6 kbps data, it is transferred to the 1/3 rate convolutional encoder through 8 bit data bus by the CPU. The output of the encoder is interleaved. The interleaved data are orthogonal-modulated to 64-ary Walsh codes, then the 307.2 ksps modulated signals are spread with 42 bits long PN code with 1.2288 Mcps chip rate. Therefore, the processing gain is 128. The spread data stream is split into I and Q channel, and OQPSK-modulated with short PN code which are generated by 15 bit shift registers. The spread I/Q channel data is baseband filtered by a 48th order FIR filter and then sent to the RF subsystem.

For reception, I/Q signals received from the RF subsystem are transferred to the searcher through a buffer by CPU. The searcher picks the strongest pilot using a PN code correlator; synchronizes with the strongest BS's PN offset, and assigns the multipath signals to each finger. Each finger correlates input signal with the assigned PN signal to get the energy, and then each finger output is merged in the combiner. The demodulated output from the rake receiver which is composed of three fingers and one combiner, is deinterleaved and decoded by the Viterbi decoder to correct channel errors. Finally, we get voice from vocoder.

The transmission and reception are two physical layer operations of the MS. Table 2 presents the physical layer parameters and

Table 1. Specifications and features of CDMA mobile station.

Parameters		Features	
Items	Spec. 1st	CDMA Specific Features	General Features
Volume (cc)*	240	- SMS - Data & G3 fax - Sleep Mode	• Call Features - Any Key Answer - Auto Redial & Answer - DTMF Dialing - Auto NAM Selection - Multiple NAM Capability - Speed Dialing - Call In Progress Recognition - Alphanumeric Display • Control Features - Multiple Call Timer - Signal Strength Indicator - Auto Power Save and Down - Call Restriction - Lock Option
Weight (g)*	260		
Standby Time* (hour)	33~25		
Talk Time* (min.)	150		
Max.Tx. Power (mW)	200		

* Exact values depend on manufacturers.

their role, for the forward link and the reverse link based on Fig. 1 [1], [2].

2. RF Subsystem

The RF subsystem upconverts the filtered baseband I and Q channel data into RF signal for transmission; downconverts the received RF signal for reception. The subsystem provides timing and frequency information, and performs transmit power control. It is connected to the antenna directly and is controlled by the digital subsystem and mobile station modem (MSM) ASIC.

As shown in Fig. 1, for transmission, the filtered outputs are four times over-sampled for 8 bits D/A conversion, and then the converted analog output is up-converted to 4.95 MHz intermediate frequency (IF), 114.99 MHz IF, and finally 824~849 MHz. In

Table 2. Physical layer parameters of mobile station.

Parameters	Receiving Path	Transmitting Path
Frame Quality Indicator	CRC check to detect frame error	12 bit CRC at 9,600 bps, 8 bit CRC at 4,800 bps
Channel Decoding & Encoding	Viterbi decoding of convolutional code with $r = 1/2$, $K = 9$	$r = 1/3$, $K = 9$ convolutional encoding, output rate is 28.8 kbps
Interleaving	block deinterleaver (span = 20 ms)	block interleaver (span = 20 ms) to randomize the burst error
Walsh Codes	- used to distinguish between different logical channels - seperates in the same cell (spreading is accomplished by this)	- used for a 64-ary orthogonal modulation - Coherence is assumed to be maintained over one symbol
Long PN Code	decoding using stored same long code generator, but seed is received from BS	- seperates users in the same cell (spreading is accomplished by this) - is used for the mobile user identification
Spreading Demodulation/ Modulation by Short PN Code	QPSK demodulation (seperates cells/sectors of cells) by rake receiver	OQPSK modulation (to avoid the amplitude variation inherent in QPSK, it makes transmit amp. design easier)
Spectral Shaping Baseband Filter	analog RC Filter	48 tap digital FIR Filter
Rx. or Tx.	uses the rake receiver to resolve multipath signals	- uses power control - is gated on-off pseudo-randomly at 1.25 ms interval to reduce self-interference

the FM, the analog baseband signal is converted to FM signal using carrier generating frequency synthesizer.

For reception, the RF received signals are bandlimitted to 1.23 MHz, downconverted to 70 MHz IF, 4.95 MHz IF I/Q

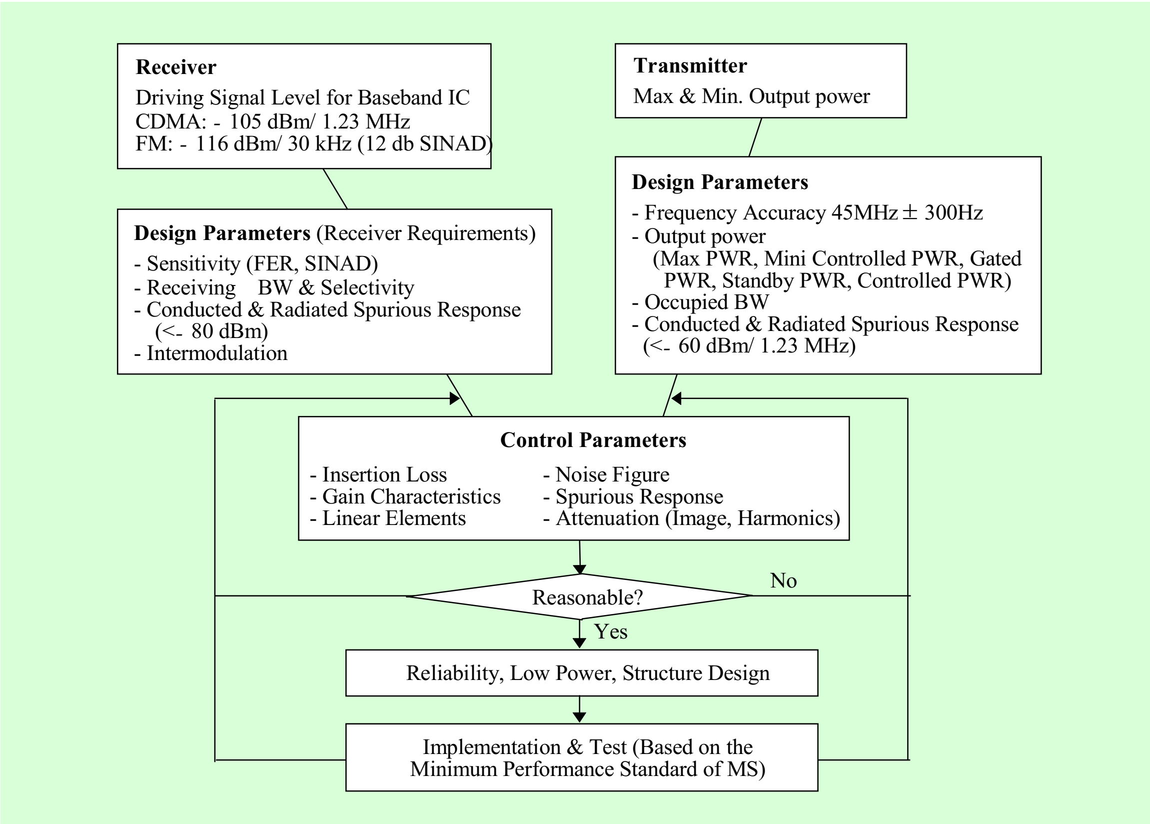

Fig. 2. Transmitter and receiver design procedure.

signals, and baseband input signals in turn. Then the baseband signals are 4 bit A/D converted to be input to the digital subsystem. In the FM, we get the baseband analog signal from the narrow-band FM signal using discriminator detection.

Power control is defined as an adjustment of the transmitting power to solve the so called near-far problem. It is to receive all serving MS signals with equal and minimum power at the BS. The open and closed loop power controls are used. The open loop power control is primarily performed by the MS. It is accomplished in two steps: the estimation of the received power and the adjustment of the transmit power based on the estimation. The control equation which states that the sum of transmit and receive power remains constant, is used. It assumes the forward path loss is the same as the reverse path loss. Since the received signal has the large dynamic range from −105 dBm to −25 dBm, the power control is done by the fast (20 ms time constant) high gain control (80 dB). The closed loop power control is a fine adjustment of the transmit power. It is accomplished in three steps:

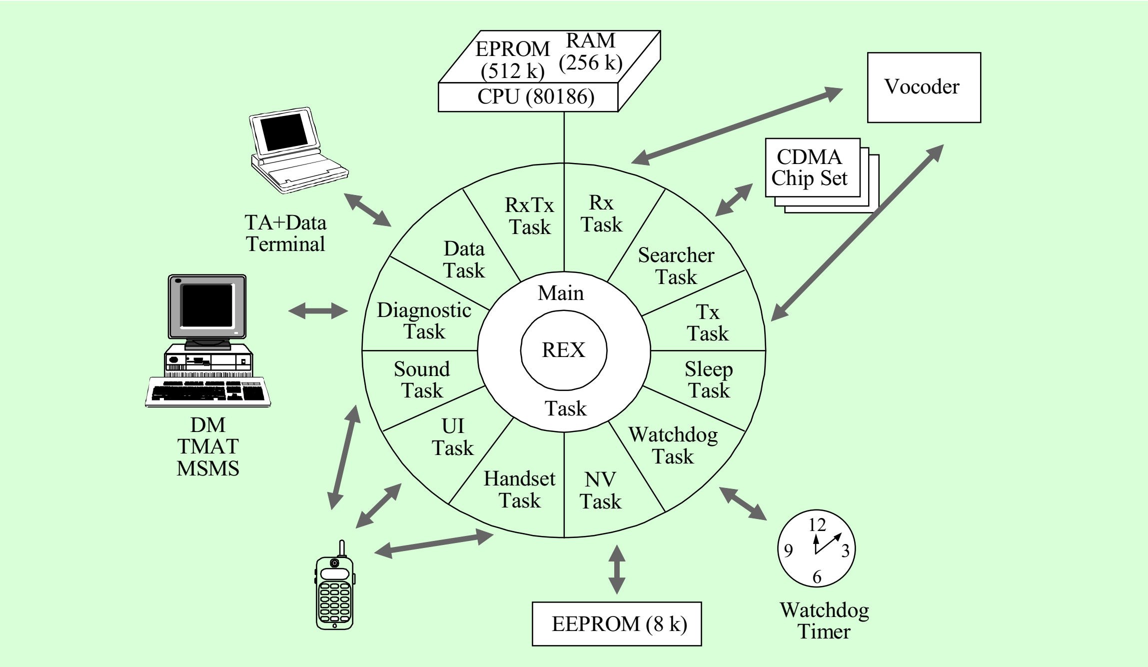

Fig. 3. Structure of CDMA mobile station SW.

BS measures the received E_b/N_o, BS compares the measured E_b/N_o with the predetermined threshold, and BS commands MS to adjust transmit power by the 1 dB step. The BS sends the power control bits every 1.25 ms. The MS decodes the control bits at the demodulator and send it to the AGC circuitry.

Figure 2 shows a design procedure of the RF transmitter and receiver. We set the input level of the baseband analog IC as a reference point for the receiver design; we set the minimum and maximum output power as a reference point for the transmitter design. Then, we determine each design parameter within the allowable values to meet the minimum performance criterion. We used software [3] to design the RF subsystem and compared the simulated results with test results later.

III. MS CONTROL AND CALL PROCESSING

1. Control and Inter-task Operations

The MS software performs many tasks and task scheduling is based on the multitask real-time operating system called REX, as shown in Fig. 3. Each task is composed of a control part and a call processing part. The control part of the main task is responsible for executing each task.

We have established the software development plan conforming to TTA-62 as summarized in Table 3.

Table 3. Evolution plan of MS SW development.

SW version	SW Functions
S1.2.1 July '94	• Basic Function - Origination/Terminating Call - Soft/Softer Handoff - Registration - Power Control - Multiplex Option 1 - Service Option 1
S1.2.2 Sep. '94	- Layer 2 - TTA-62 Message Format Compliance
S1.2.3 Nov. '94	- Hard Handoff (Multi FA, interBSC, interMSC) - Multi Frequency Assignment - Frame Staggering - Additional Function (Flash with Inform MSG)
S2.0 Mar. '95	- Authentication - Slotted Mode Paging - Voice Privacy - Data, G3 fax and SMS
S3.0 '96	- Encryption - Other New Generation SW

2. MS Call Processing

The MS call processing consists of the following four states as shown in Fig. 4:

- Initialization state: selects and acquires either a CDMA or analog system.
- Idle state: monitors messages on the paging channel.
- System access state: sends messages to the base station on the access channel.
- Traffic channel state: communicates with the base station on the traffic channel.

These states are delineated in CDMA MS SW analysis. The key aspects of the processing are discussed.

A. Initialization State

The MS performs the following steps (see Fig. 5):

- After the power is turned on, it enters the
  initialization state;
- selects the system in service: CDMA or Analog system (system determination substate);
- goes to analog system initialization (pilot channel acquisition substate), if Analog is selected; acquires a Pilot Channel, if CDMA is selected, and takes the following three more steps;
- obtains system configuration and timing information (sync channel acquisition substate);
- synchronizes system timing and long code timing (timing change substate);
- sets the paging channel with primary paging channel, and then goes to idle state.

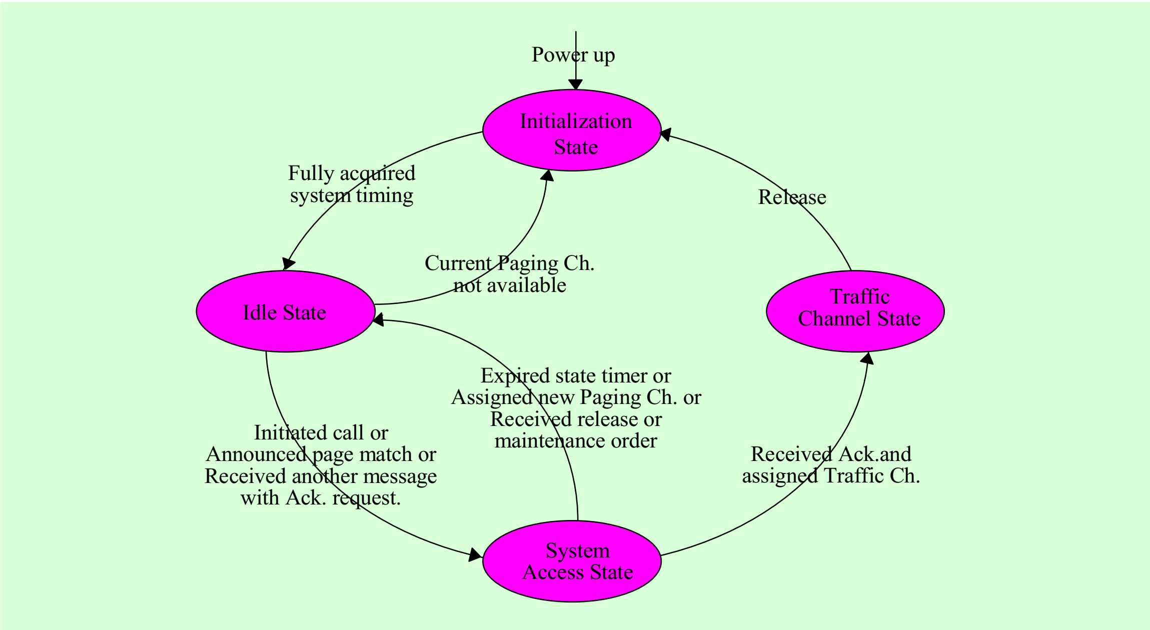

Fig. 4. MS call processing diagram.

The pilot channel aquisition is the most important because the PN code synchronization takes place in the acquisition and is a precondition for the link establishment with the BS. The double dwell serial search technique is employed for the acquisition [4], [5].

B. Mobile Station Idle State

In the idle state, the MS monitors a specified primary paging channel and receives the *system overhead messages*. Based on the received message, the MS changes the saved BS configuration parameters, selects a new paging channel by a Hash operation and accomplishes an idle registration. Then, if the MS detects the other stronger pilot channel signal, the idle handoff operation takes place. If the MS receives the *page message*, the page match operation takes place to identify the incoming call and goes to the system access state to send the *page response message*. If it initiates a call, the MS initiates a message transmission and goes to the system access state. When the power is off, the MS stores the parameters and performs other registration procedures.

C. System Access State

In this state, the MS sends the BS messages on the access channel and receives messages from the BS on the paging channel. The following steps take place in this state:

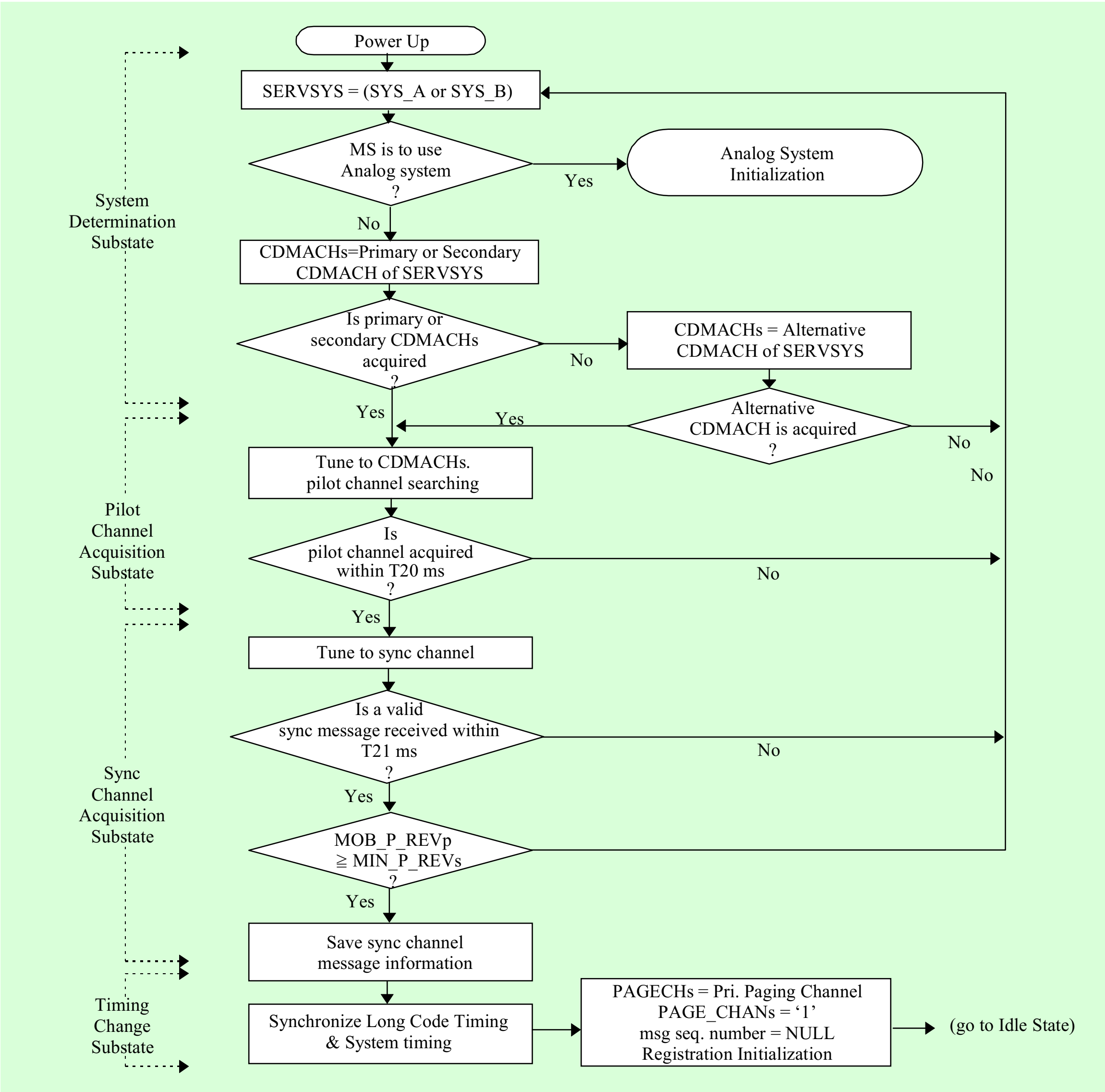

Fig. 5. Initialization state flowchart.

- The MS monitors the paging channel until it has the current configuration message (update overhead information substate);
- for an originated call, send an *origination message* (origination attempt substate);
- for a terminated call, send a *page response message* (page response substate);
- for registration, send a registration message (registration access substate);

- for message transmission, send *data burst message* (message transmission substate);
- upon receiving a message from the BS, send the response (MS order/message response substate).

D. Traffic Channel State

This state consists of four substates: initialization, waiting-for-order, waiting-for-MS-answer, and conversation. The state starts with the initiation substate. In the substate, the MS verifies the forward and reverse traffic channels by transmitting a preamble, receiving the BS ack, and then transmitting the null traffic data every 20 ms. After the sucessful verification, the state is changed to the waiting-for-order substate. In the waiting-for-order, either call origination or call termination can happen. For an originated call, the MS sends an origination message. After receiving the service option (SO) response order, the MS confirms the SO by sending ack. Then, after it receives the *alert with information messages* with ringback tone ON and OFF signal from the BS, the MS goes into the conversation substate. For a terminated call, upon receiving the service option response order, the called MS sends an ack to confirm the SO and receives an *alert with information message*. When the subscriber at the MS responds, the MS goes into the waiting-for-MS-answer substate, sends a connect order and goes into the conversation substate to start exchanging primary traffic packets with the BS. When the call is disconnected, MS receives the release order.

IV. MOBILE OFFICE SERVICES

We have developed three types of non-speech services and we call them as the mobile office services. They are async data, G3 fax and SMS that deal with texts, images, messages, and database [6]-[9]. To develop the mobile office services, SO processing and data interface functions must be implemented. The SO number 1, 4, 5 and 6 are assigned for speech, async data, G3 fax and SMS, respectively. The selected service is processed by the SO negotiation procedures specified by the TTA-62.

1. Async. Data and G3 Fax Service

A. Configuration

Figure 6 shows the configuration of the async data and G3 fax serving system. Async data and G3 fax have the same configuration in CDMA cellular networks. Application software and SO distinguish from Async data and G3 fax service.

MS side is composed of an MS labeled as MT2, and two external devices connected with RS-232C. One external device is a non-ISDN data terminal labeled as TE2 which provides an application software. The other is a terminal adapter, TA, that gives an interface between TE2 and MT2. TA supports the standard modem command set for async data and extened AT command set

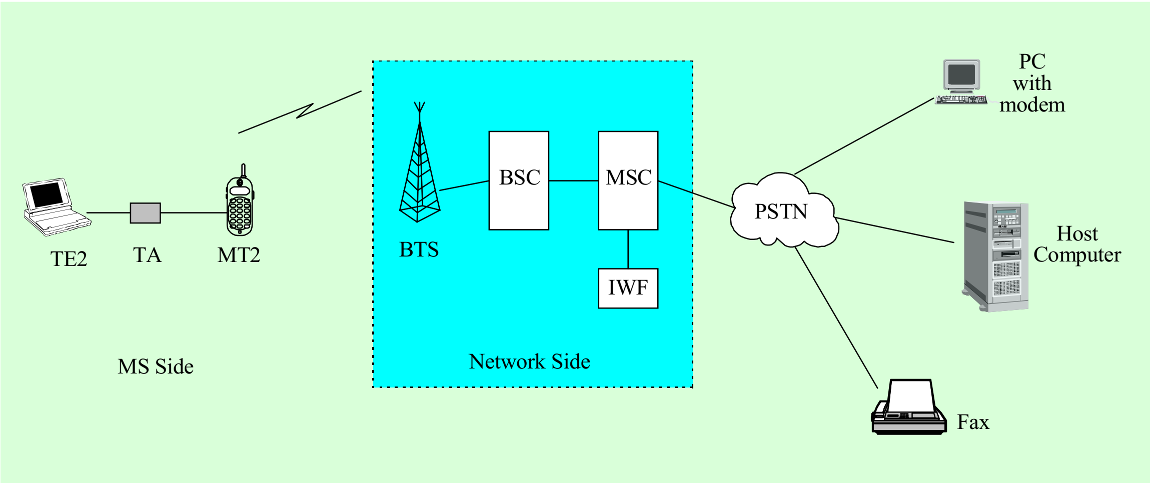

Fig. 6. Configuration of the async data and G3 fax serving system.

for G3 fax. And also, we designed TA to have protocol stack except radio link protocol (RLP) to reduce MS load.

Information transmission is accomplished by using a data or a fax modem. In the CDMA cellular network, the data and fax modem are in an interworking function (IWF) in the MSC. IWF is a pool of modems. It terminates cellular-specific modem and fax protocol, and converts the protocol into a standard modem and fax protocol. The IWF assigns one modem for one data service user. So, a mobile subscriber should control the assigned modem by using the modem commands over the air to initiate or receive a data or a fax call.

B. Protocol Stack

The reference model of the protocol stack is shown in Fig. 7 [6]. Transport control protocol and internet protocol

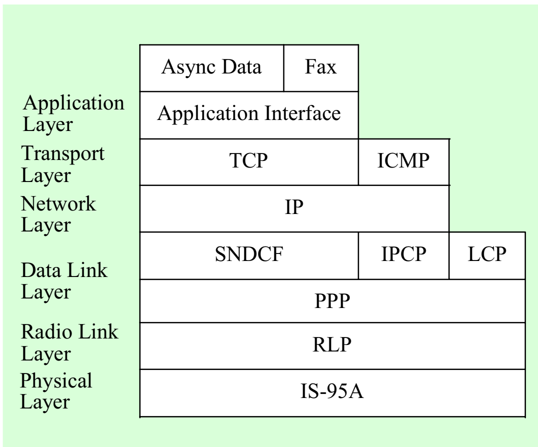

Fig. 7. The reference model of the protocol stack.

(TCP/IP) has been widely used in computer networks for transport layer and network layer protocols. To apply the TCP/IP to wireless environment, sub-network dependent convergence function (SNDCF), link control protocol (LCP), internet protocol control protocol (IPCP) and point-to-point protocol (PPP) are used for data link layer protocols. Also, RLP is used for error recovery of the radio link. This protocols are as follows [8].

- Application Layer
  Application compatibility for async data and fax is achieved by standard computer software. Data terminal such as a notebook computer provides the application software which uses the standard modem commands for call initiation and response. Application interface (AI) has a role of the modem control and modem command processing for application program.
- Transport Layer
  TCP is intended for providing the reliable full duplex data transmission.
- Network Layer
  IP is a network protocol for transmitting blocks of data called datagrams from sources and destinations, where sources and destinations are hosts identified by fixed length addresses.
- Data Link Layer
  SNDCF performs header compression on the headers of the TCP/IP. PPP provides the simple link to transport the packets between both peers. LCP is used for initial link establishment, and negotiation of the optional link capabilities. Internet protocol control protocol (IPCP) negotiates the IP addresses and TCP/IP header compression.
- Radio Link Layer
  RLP is a data link layer protocol for reducing an error rate typically existed on the TTA-62 reverse and forward traffic channels. It is implemented in an MS and BSC. RLP layer carries the variable length data packets of the application layer into TTA-62 traffic channel frames for transmission. RLP generates and supplies exactly one frame to the multiplex sublayer every 20 ms.
- Physical Layer
  Physical layer of the IS-99 is the same as TIA/EIA/IS-95A. Our system has the TTA-62 traffic channel which is divided into 20 ms time slots. Each time slot can be used to transmit a fixed amount of bits. It has been defined as a multiplex option 1.

C. Designed Protocol and Signaling Procedure

Figure 8 shows a proposed protocol stack for the data services. TE2 has application layer for async data and fax. TA has application interface for modem command processing and data compression negotiation, TCP, ICMP, SNDCF, IPCP, LCP and PPP. MT2 has RLP for ARQ on air interface and physical layer of TTA-62. TE2 and TA is connected with RS-232-C serial interface. TA and MT2 have serial interface also.

Figure 9 represents a signaling procedure for a data service call. To transmit the information using TE2, at first the subscriber runs the application SW and accomplishes the modem initialization commands. Then TE2 sends those

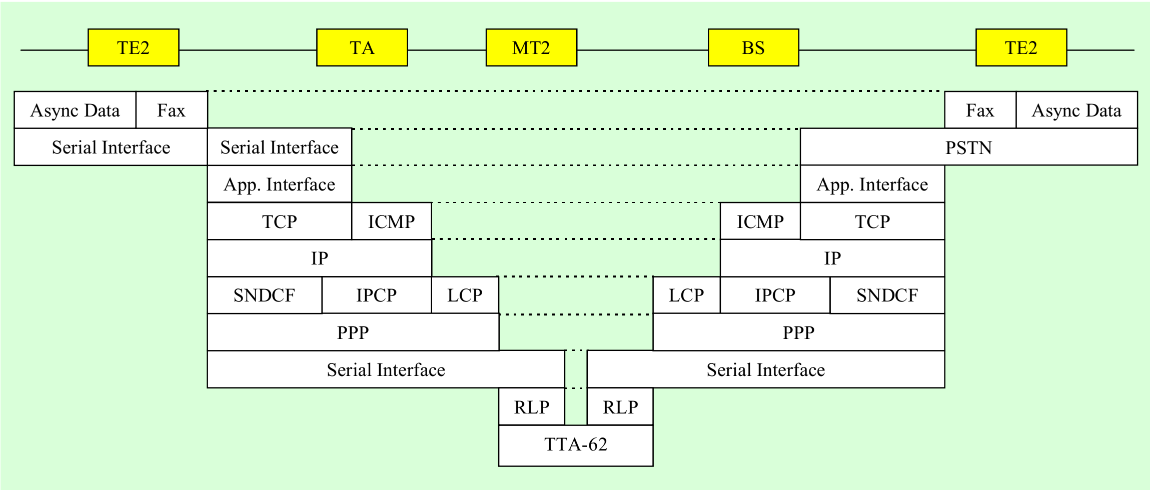

Fig. 8. The architecture of the protocol stack in CDMA async data and fax serving system.

commands to TA. TA stores the modem configuration information and returns the response. TA sends a start packet (TA_SO_START) with determined SO to MT2 and waits for the acknowledgment from MT2 (DS_START_ACK).

For mobile originating call (A), the subscriber sends a modem dial command (ATD#, # means terminated user number) on TE2. TA recognizes it and sends the call origination (TA_SO_REQ) packet to MT2 with the dial number and SO 4 or 5. According to the packet from TA, MT2 sends an *origination message* to the BS for requesting a call. According to the TTA-62 call processing, MT2 and BS process the *traffic-channel initialization substate* and go to the *conversation substate*.

In the case of mobile terminated call (B), BS pages an MS with page message with SO 4 , 5 or 0xFF. If the call is requested from PSTN, MSC doesn't identify the type of call, and doesn't know the SO for paging. So we used 0xFF as a SO number for PSTN call. If the MT2 receives the *page message* with 0xFF, MT2 determines the SO which is currently available by MS, and sends the *page response message* with the determined SO. After *traffic-channel initialization substate* and *waiting for order substate*, if MT2 receives the alert with information message from the BS, MT2 sends the alerting packet (TA_SO_ALERT) to TA for ringing. TA sends modem ring message ("RING") to TE2. TE2 answers with modem answer command (ATA). TA sends the answer packet (DS_SO_ANSWER) to MT2 for answering a call. Then MT2 sends a connect order to BS. Then MT2 and BS go to the *conversation substate*. In the *conversation substate*, MT2 accomplishes the call setup according to SO negotiation, initializes RLP and informs TA of

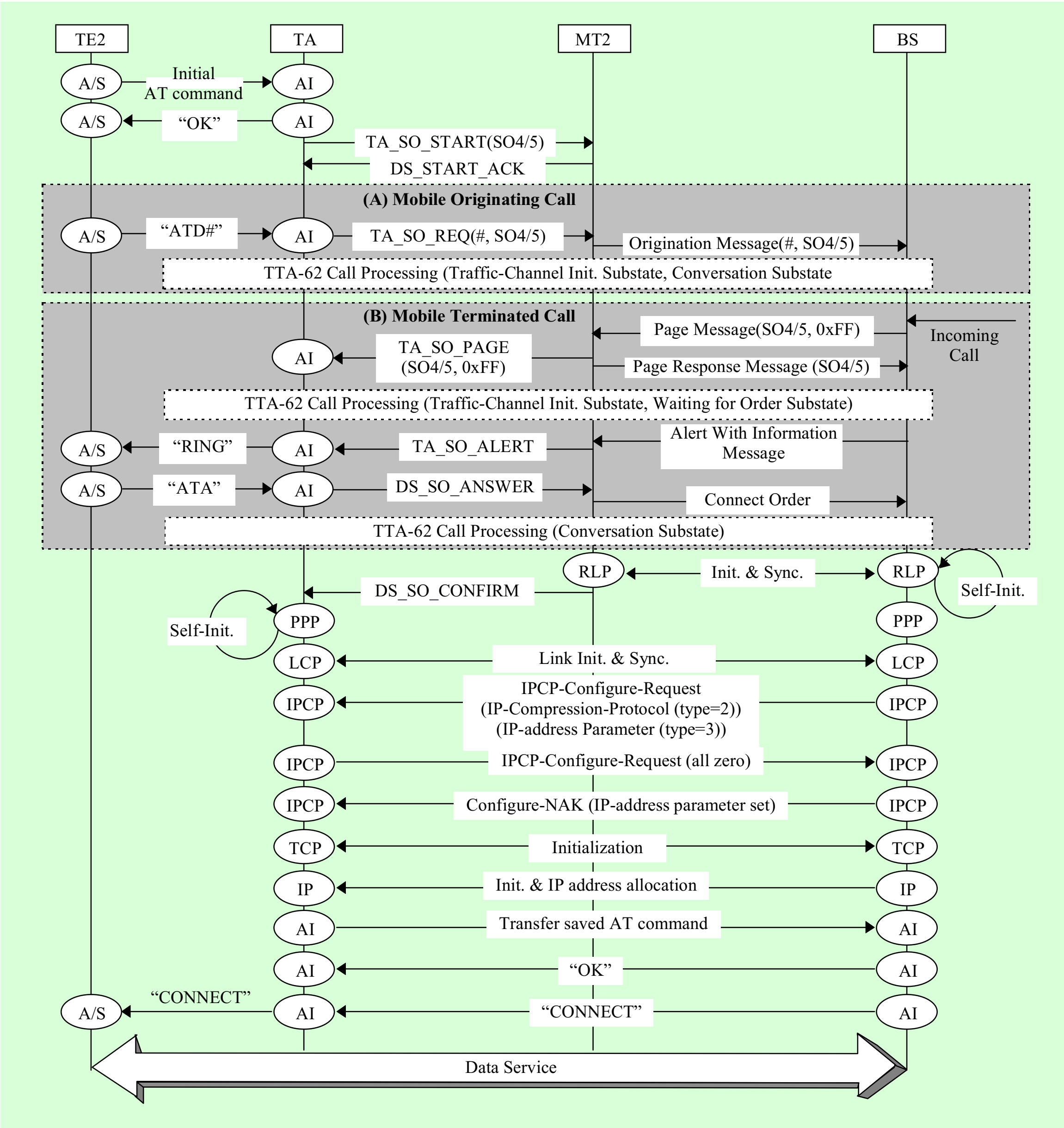

Fig. 9. Signaling procedure for the mobile originating call.

call connection with call connected packet (DS_SO_CONFIRM). Self-initialization of PPP in TA and the BS is accomplished. LCP initialize the link and synchronize the protocol each other. IPCP negotiate the IP address. TCP/IP is initialized and the BS allocates the temporary IP address to the MS. Then TA transfers the pre-saved modem commands to the BS through protocol stack and waits for the modem response by IWF on MSC. If a modem of the IWF is connected with the other part modem, TE2 receives "CONNECT" result code from the IWF modem. Then it is possible to use the corresponding service.

D. Quality of the Service

Since multiplex option 1 limits the data rate to 8.55 kbps, it is impossible, unfortunately, to fully get the same data rate as that of the wired network environment. Also, the overhead of protocol stack reduces the pure data rate. PPP uses the principles described in ISO 3309-1979 HDLA frame structure, more recently the fourth edition ISO 3309-1991, which specifies modifications to allow HDLC use in asynchronous environments. The control escape octet is defined as hexadecimal 0x7d. After FCS computation, the transmitter examines the entire frame between the two flag sequences. Each flag sequence, control escape octet, and any octet that is flagged in the sending async-control character-map (ACCM), are replaces by a two octet sequence consisting exclusive-or'd with hexadecimal 0x20. However, this octet stuffing increases the PPP header size and has an effect of the performance degradation. TCP/IP datagrams are transported over a serial IP link from MS and it has also their own header. Since transmission link is too slow by limitation of wireless link, the big TCP/IP header size may degrade the performance. If sending application prepares a big data such as a file or fax data, the performance will degrade seriously. So IS-99 recommends the SNDCF layer which reduces the TCP/IP header size by Van Jacobson TCP/IP header compression algorithm. However, unfortunately, the retransmission frame does not use the algorithm. So we cannot achieve the data rate higher than 4.8 kbps. RLP layer carries the variable length data packets to its upper layer over both TTA-62 reverse and forward traffic channel. It generates and supplies exactly one frame to the multiplex sublayer every 20 mS. RLP is pure NAK-based selective repeat protocol. When the RLP layer of the receiving part detects an error frame, it sends NAK requesting frame for retransmission. Also, if the retransmission frame has an error again, it sends NAK frame again. However, both sending and receiving part cannot wait forever for compensating the error continuously happening in a row. So IS-99 sets the timer for missing frame and limits the retrials to three times. RLP aborts the attempt after three times retrials and passes whatever it has gotten to its upper layer. The throughput of TCP is dependent on FER of RLP frames eventually passed to its upper layer and average round trip delay of RLP frames. TCP has a go back N ARQ and sliding window mechanism. If receiving application generates response immediately after data arrives, a short delay may permit the acknowledgment to piggyback on a data segment. However, if receiving application don't response immediately (in case of fax call or file transfer), receiving application waits to receive the end of data. Generally, a sending TCP delays sending a segment until it can accumulate a reasonable amount of data. In this case, if sending application generates data one octet at a time, TCP will send the first octet immediately. Then, until acknowledgment arrives, TCP accumulates additional octets in its buffer. This is known as Nagle algorithm which is used to reduce the number of small packets sent by a host. However, because the sending application generates burst data for the file or fax data and the application is fully fast compared to the wireless network, TCP buffer may overflow for waiting ACK and transmission timer for application protocol, such as file transfer protocol and T.30 protocol, will be timed-out. So this Nagle algorithm can impede performance.

E. Implementation and Test Results

If the call is set up as in Section C, data or fax images can be transmitted and received by TTA-62 primary traffic channel. For the data processing, we implemented data task. Data task communicates with TA by SIO (Serial I/O) interface. We also used the circular buffer for each receiving and tranmitting of data. Table 4 presents the test results based on test environments of Fig. 6. This test excludes the mobility and handoff. Transmission rate is up to 4800 kbps. Criterion for passing is determined as the case of at most one fail of 10 or more trials.

Table 4. Test results.

Test Items	Detailed Test Items	Test Results
Async. Data Service	mobile-to-mobile	pass
	mobile-to-land	pass
	land-to-mobile	pass
Async. File Transfer Service	mobile-to-mobile	pass
	mobile-to-land	pass
	land-to-mobile	pass
G3 fax Service	mobile-to-mobile	pass
	mobile-to-land	pass
	land-to-mobile	pass
Performance Test	Bit Error Test	10^{-6}

2. SMS

A. Overview and Protocol Stack

SMS is defined as the exchange of short alphanumeric messages between MS with external device and the short message service - message center (SMS-MC) in MSC. Each short message is delivered by *data burst message* on the paging, access channel without connecting with traffic channel, or on the traffic channel by store & forward scheme. It has a characteristic that the SMS is provided by the store and forward method through MS and SMS-MC, and also it is possible to service as a normal and extention mode for the long message. Generally, the service types are classified as follows :

- CDMA digital paging teleservice
- CDMA cellular messaging teleservice
- CDMA voice mail alert/notification teleservice
- CDMA cellular broadcast teleservice.

The SMS protocol stack is shown in Fig. 10. The link layer represents the CAI and messsage processing procedure on TTA-62. The relay layer provides the interface as a network router between the transport layer and the link layer used for message transmission. The transport layer manages the end-to-end delivery of messages and it is responsible for receiving SMS transport layer messages from an underlying SMS relay layer, interpreting the destination address and other routing information, and forwarding the message via an undelying SMS relay layer. The teleservice layer locates an end of stack and supports the provided service. To provide the SMS, the teleservice layer uses five kinds of messages for message delivery, submission, cancellation and acknowledgement. All these are packed in the CHARi field of data burst message and exchanged.

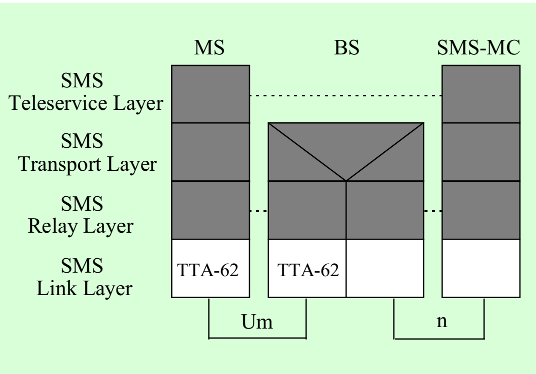

Fig. 10. SMS protocol stack.

B. SMS Mobile Station

IS-637 [8] recommends that the MS supports the interfaces with display unit and keyboard for message entry. It is considered the fact that keyboard on notebook is more convenient than small entry unit on MS. It is the most resonable scheme because notebook also can be used data/fax services.

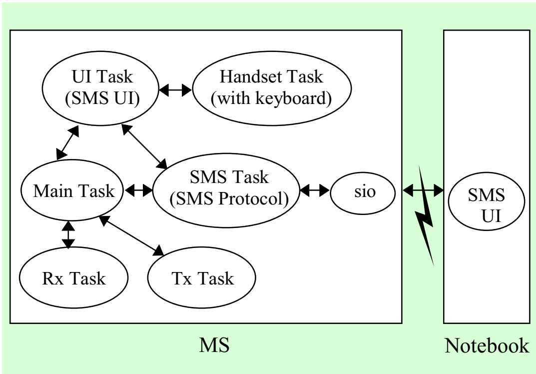

Fig. 11. Structure of MT2 software for SMS.

To implement SMS, the MS has to have the following serveral functions: SMS protocol processing, SO negotiation, user friendly interface (message receipt, storage, construction and origination, display of Korean letters, etc.). Figure 11 shows a structure of SW for SMS. The SMS task communicates with the external device (TA and TE2), which has the protocol stack and processes the *data burst message* from main task. The main control task deals with Tx task for transmission and Rx task for receiving. Notebook has a function for interpreting and displaying of information such as Korean letters. The origination and termination call procedures are the same as speech communication except that the *data burst* message are exchanged instead of speech and SO number is different.

V. TEST SYSTEM DEVELOPMEN T FOR PERFORMANCE EVALUATION

1. Construction of MS Test System and Test Automation

A. CDMA MS Test Standard

CDMA MS test requirements are determined by the minimum performance standard [10]. These requirements are needed to ensure operations above certain performance level. This standard specifies environmental requirements, protocols, and Tx/Rx characteristics about CDMA MS. Analog related items are optional. Receiver test requirements are concentrated on demodulation performance under various transmission conditions such as AWGN and multipath fading. Test items are frequency, system acquisition under handoff, demodulation, receiver performance, limitations on emissions and supervision. The transmitter tests are concentrated on transmitted waveform quality, power control performance, absolute power characteristics, and spurious emissions such as frequency, handoff, modulation, output power, and limitations on emissions.

B. Construction of Test System

A block diagram of test setup is shown in the Fig. 12. It is necessary that a test equipment functioning as a BS provides specific signals and signaling messages to establish and maintain a CDMA link. We used Qualcomm roving test system (RTS). In order to reduce electromagnetic influence (EMI) from the forward link, we designed a shielding chamber for the MS. Other test equipments used are; a MP-2500 NoiseCom channel simulator, a HP8593E spectrum analyzer with HP85725A CDMA personality, a ρ-meter (Waveform Quality Meter) including HP83203A CDMA adaptor, a coding accuracy equipment, an AWGN generator, and a CW generator.

C. Automation of Test Procedure

CDMA MS tests are composed of many complicated parameter setting of BS and MS as well as test equipment calibration. To prevent mistakes caused by manual operation of whole test procedure and to save time for repetitive test data acquisition, remote control program using HPIB controller has been developed. This programs are based on Windows operation. Following the Fig. 13, it contains the automated functions which are equipment calibration, test environment setting including forward parameter and channel simulator setting, test-

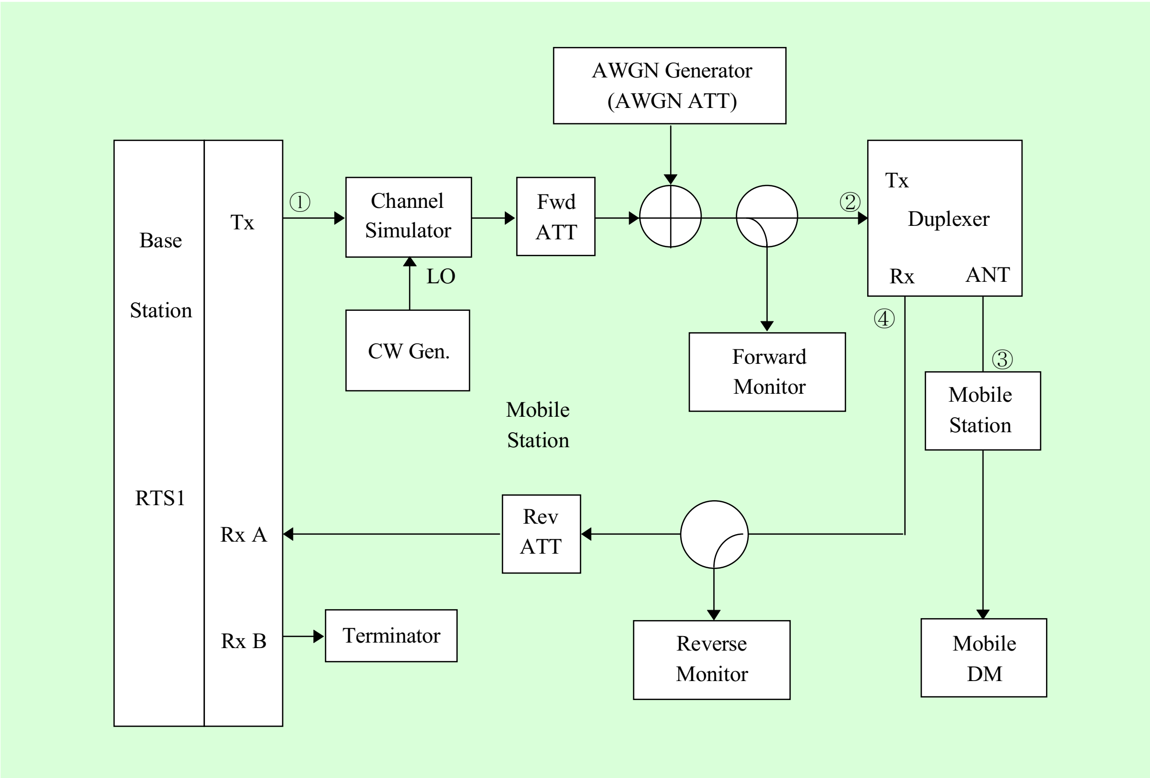

Fig. 12. CDMA MS test system block diagram.

ing, result analysis, data storage/display and printout. An example of the test results is shown in Fig. 13. This is the receiver characteristics in the multipath fading channel environment, which is based on the receiver test flow of Fig. 14. In the similar way, all the test flows of the performance standard [10] are made, and MS test can be performed automatically by simple personal computer manipulation.

2. TTA-62 Message Analysis Tool

All call processing of MS and BS are accomplished by exchanging the signaling messages defined in TTA-62. If there is any problem during a call setup which results in an abnormally termination or in some unknown states, we want to verify whether the messages are exchanged correctly or not. TTA-62 message analysis tool (TMAT) is an analysis tool which is used to validate the message flows.

A. Logging of Message

MS diagnostic monitor (DM) monitors the MS. It displays the real time status of MS, tracks the MS SW, or saves records of power control, signaling message parameters, etc. If the DM requests the saving

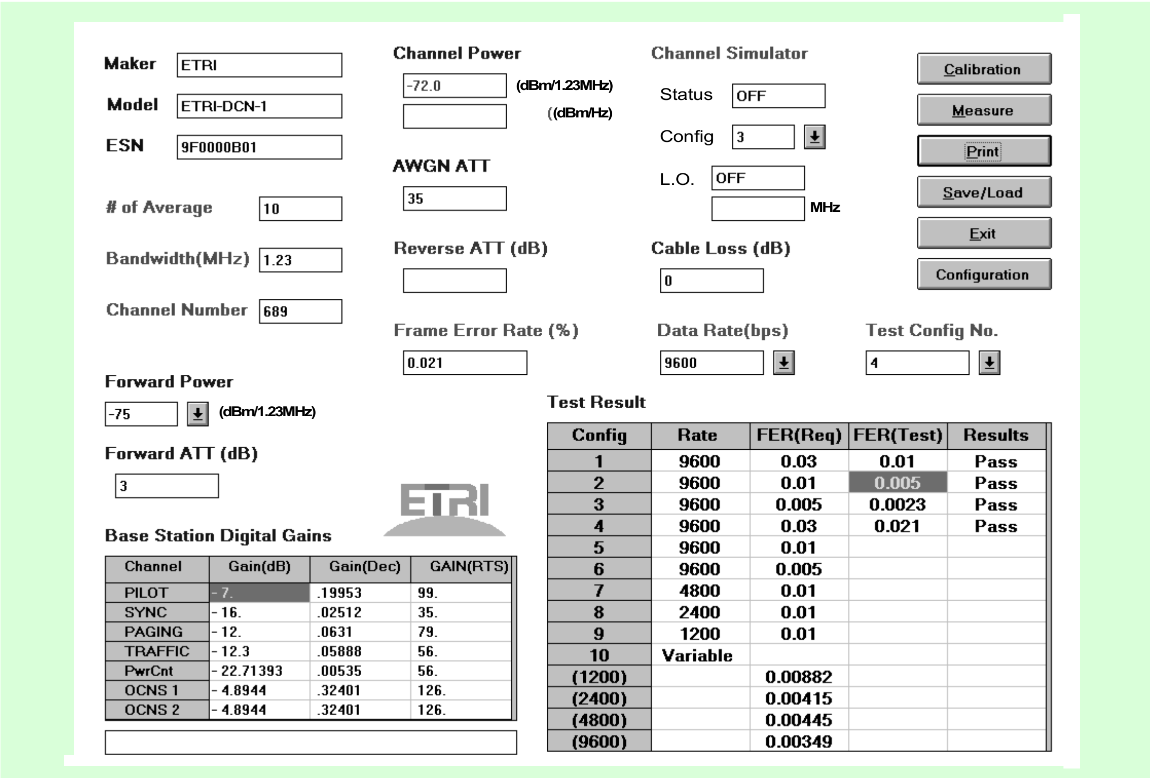

Fig. 13. Automation SW for CDMA MS receiver test.

of signaling message, the MS collects messages received or transmitted and sends it to the DM. The message packets exchanged between the MS and the DM are distinguished by the command code in the first byte of each packet. Figure 15 shows the response packet structure without the command code. It consists of logging header and data body.

The logging header has the information of logged data which are **len** (total data length), **code** (signaling message types: access, sync., paging and traffic channel) and **ts** (receiving or transmitting time). And also, data body contains the message information like length, type, data and CRC. This data body depends on TTA-62 signaling message format. DM saves the packet as a binary file for each message because it cannot display all of them on screen by real time.

B. Message Analysis

As shown in Fig. 16, TMAT reads a logging header from the saved binary file, and then parses **len**, **code** and **ts**. Then it reads the remaining data according to the data length, parses the message field according

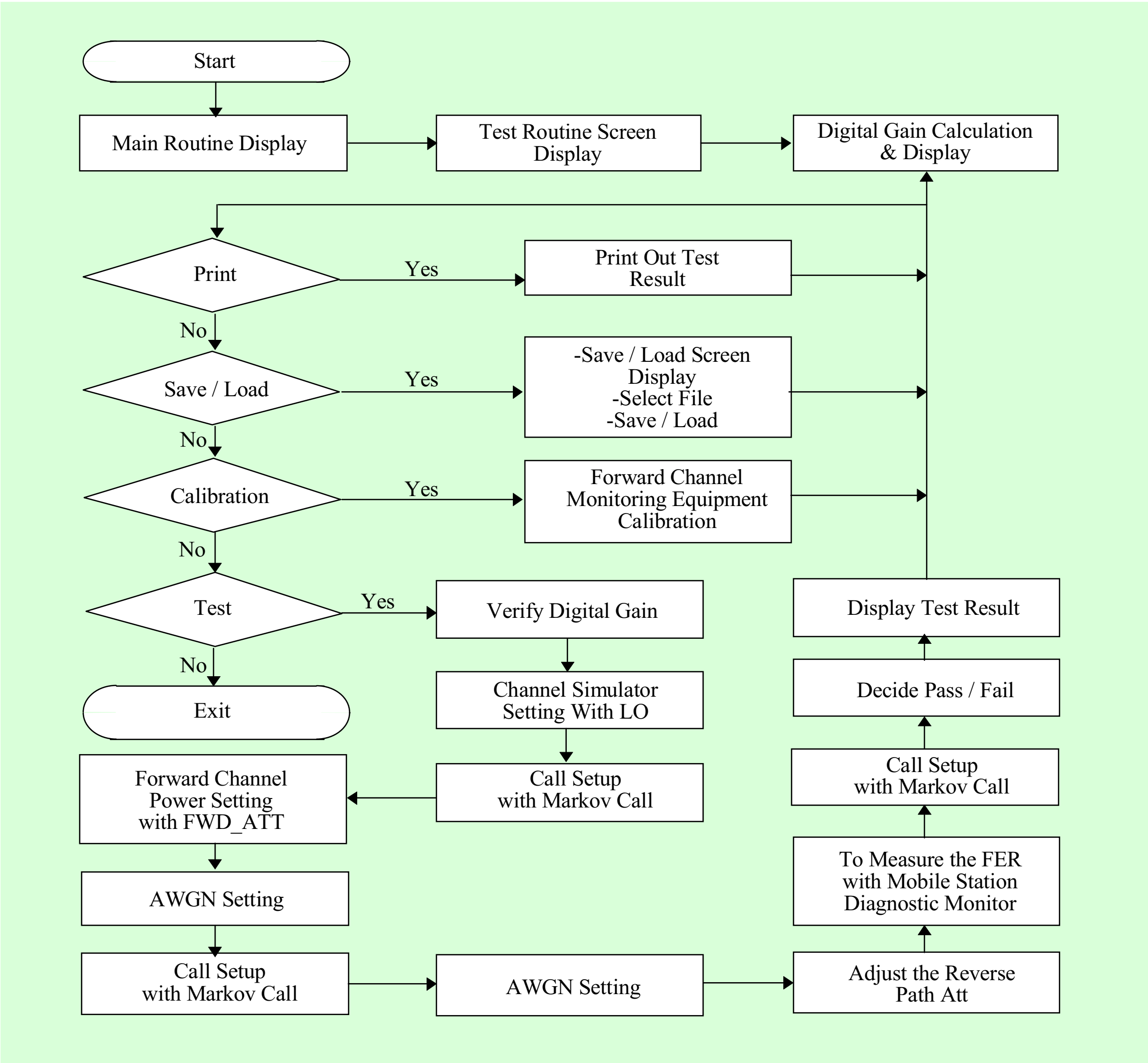

Fig. 14. Flowchart for the receiver characteristics test on the multipath fading channel environment.

to the message type, saves them as a ASCII file, and finally displays on the screen.

We show in Fig. 17 an output result of TMAT which is a system parameter message of paging channel received from BS.

3. Mobile Station Monitoring Software

It is required for test MS and integrating test that analysis tool for each test item as well as message monitoring. Thus mobile station monitoring software (MSMS) tool was developed which based on the concept of compact for utilizing in the fields test. MSMS can analyze the message monitoring and analysis, subscriber information display, power control, handoff, authentica-

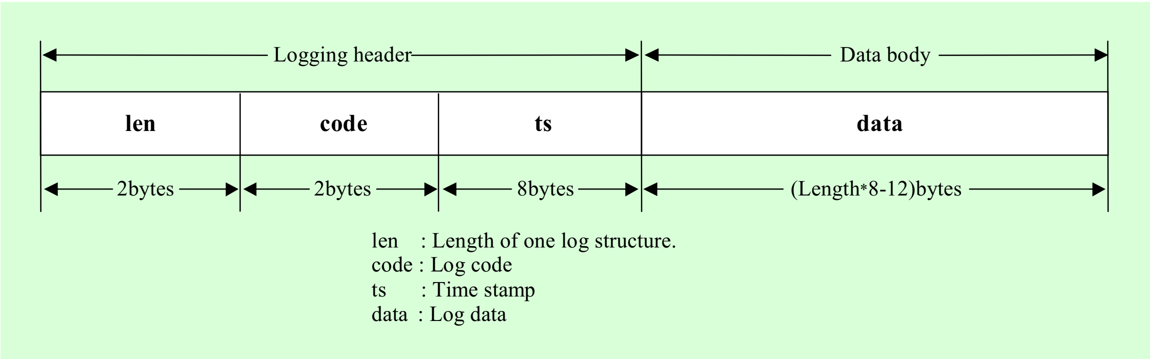

Fig. 15. Structure of logged data and message.

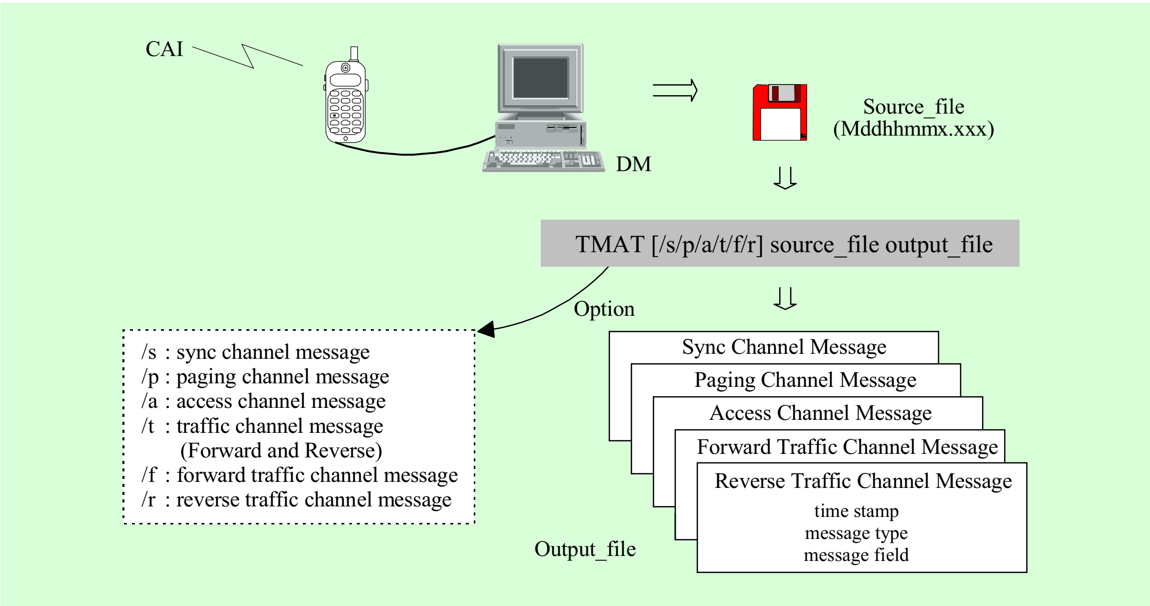

Fig. 16. Processing of message parsing.

tion, and registration function including a part of Qualcomm DM functions as shown in Fig. 18.

VI. FUTURE EVOLUTION

Our goal is to develop an MS which is easy to handle, has high performance, provides security, and is immune to EMI/EMC. The MS implementation focused on its service variety and cost. The MS is to provide services of multi-mode, multi-functions and multi-media, and, at the same time, it must be small, light, 1994/3/10 01:08:18.628 Mobile Station PAGING CHANNEL message!

Access Parameters Message

pilot_pn: 144	psist(0_9): 0	probe_pnran: 0
acc_msg_seq: 0	psist(10): 0	acc_tmo: 5
acc_chan: 0	psist(11): 0	probe_bkoff: 0
nom_pwr: 0	psist(12): 0	probe_bkoff_rsv: 0
init_pwr: 0	psist(13): 0	bkoff: 1
pwr_step: 0	psist(14): 0	bkoff_rsv: 0
num_step: 6	psist(15): 0	max_req_seq: 0
max_cap:_sz: 0	msg_psist: 0	max_rep_seq: 2
pam_sz: 3	reg_psist: 0	authentication mode: 0

Fig. 17. An output result of TMAT.

low power consumption, inexpensive, and highly reliable.

The mobile station now employs technologies such as: RF MMIC ASIC to reduce component sizes, ASIC integration of digital part, and 3 volt Li-Ion battery to reduce the battery weight and to increase its energy density about twice that of Ni-MH type. The mobile office services will have new features with smart card, caller ID, enhanced vocoder. It will offer new functions for userfriendly service as well as long talk times and high sound quality.

VII. CONCLUSIONS

In this paper, we presented the development results of a CDMA MS and its mobile office services. And also described the test system, analysis tools and results of performance analysis.

In the development process, it was necessary to verify call processing and to prove performance, which was made by implementing monitoring and analysis tool such as TMAT, MSMS and performance test system. And also it was an important thing that cooperation with Korean DMs. It would be better that if we had the more CMS testbed to test the developed features quickly.

ETRI and Korean DMs developed 2nd generation MS with volume 172 cc and weight 175 g, which is currently under commercial service. We will keep on improving the MS functions and features constantly relating with PCS and FPLMTS.

REFERENCES

[1] TTA-62, *Interim Standard for Common Air Interface for Digital Cellular in the 800 MHz Band*, 1994.

[2] R. Padovani, "Reverse link performance of IS-95 based cellular systems," *IEEE Personal Communication*, pp. 28-34,1994 3Q.

[3] EEsof Omnisys ver. 4.0, Hewlett Packard, 1993.

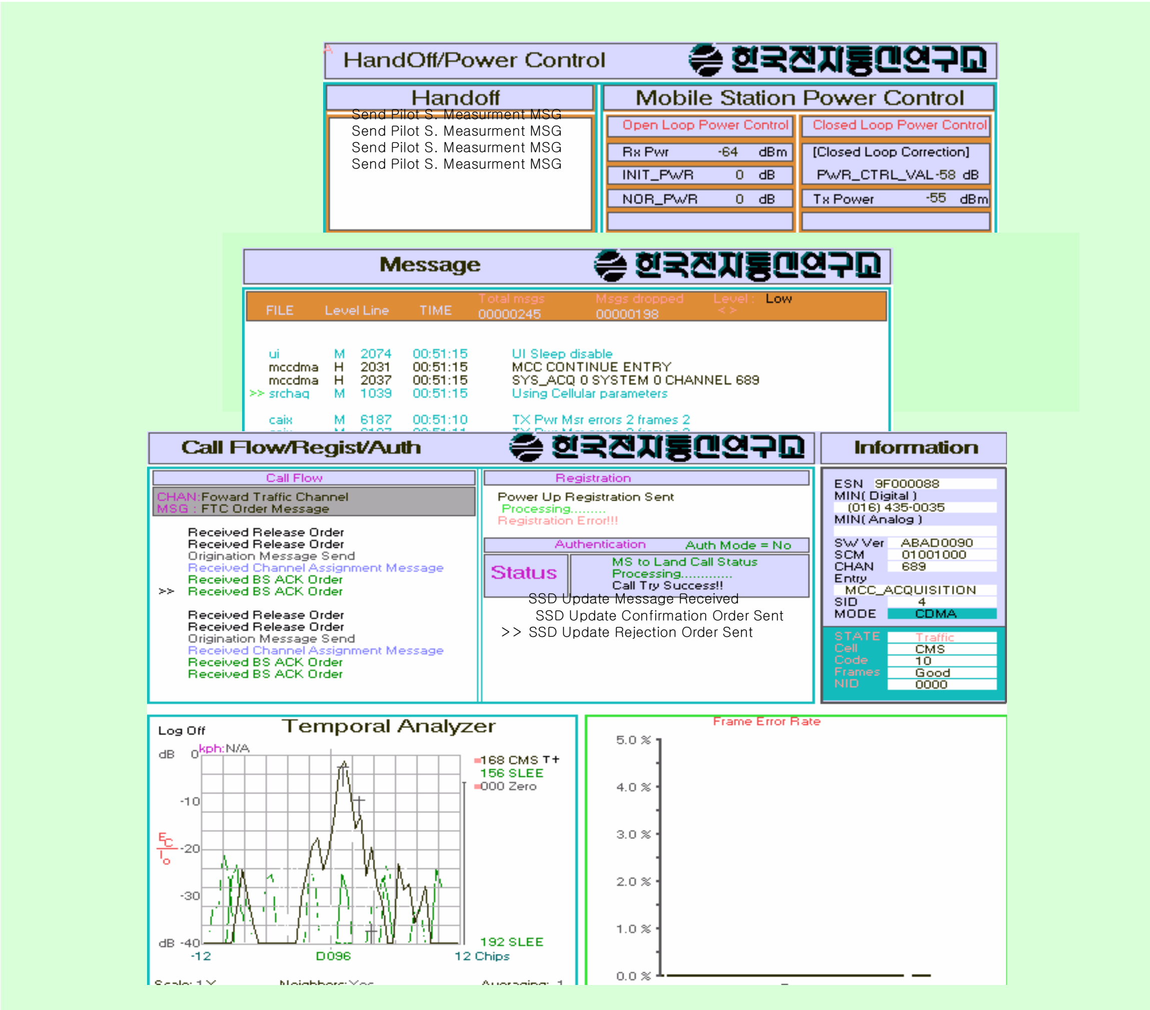

Fig. 18. Mobile station monitoring software.

[4] A. J. Viterbi, *CDMA*: *Principles of Spread Spectrum Communication.* Addison Wesley, 1995.

[5] J. K. Hinderling, "CDMA mobile station modem ASIC," *IEEE J. of Solid-state Circuits*, vol. 28, no. 3, March 1993.

[6] EIA/TIA/IS-99, *Data Services Option Standard for Wideband Spread Spectrum Digital Cellular System*, Feb. 1995.

[7] Hye-Yeon Kweon and Sun Young Kim, "A simple design of mobile station for circuit-mode data services in CDMA cellular network," *Wireless'96 International Conf. Proceedings*, vol. 2, pp. 431-435, 1996.

[8] TIA/EIA/IS-637, *Short Message Services for Wideband Spread Spectrum Cellular Systems*, Feb. 15, 1995.

[9] Hye-Yeon Kweon, "A scheme for supporting the fax service in CDMA Mobile System," *ICCS*, Nov.1996.

[10] TTA-0011, *The Minimum Performance Standard for MS in 800 MHz Band*, 1994.

Sunyoung Kim received the B.E., M.E., and Ph.D. degrees, all in electronic engineering from Dong Guk University, Seoul, Korea, in 1982, 1984, and 1991, respectively. Since 1985 he has been with Electronics and Telecommunications Research Institute, Taejon, Korea, where he is a Principal Member of Research Staff of the Radio Technology Section. From 1994 to 1996 he was Chairman of Radio Interface Study Group in SC6, TTA, Korea. He is currently involved in the development of CDMA WLL and IMT-2000 mobile station. His research interests include digital mobile communication, and adaptive signal processing. He is a member of the KITE, KICS, and IEEE.

Yoon Uh was born in Kyongnam, Korea in 1959. He received the B.E. and M.E degrees in electronic communication engineering from Hanyang University in 1982 and 1986, respectively, and Ph.D degree from Tohoku University, Sendai, Japan in 1994. He had worked at Goldstar Electric from 1986 to 1987. He joined ETRI in 1987, where he is currently working in Mobile Communication Division. His research interests include mobile communication, error-correcting coding and EMC.

Hye-yeoun Kweon

See *ETRI Journal*, vol. 18, no. 4, p. 227, Jan. 1997.

Hyuckjae Lee received the B.S degree in electronic engineering from Seoul National University in 1970, and the Ph.D. degree in electrical engineering from Oregon State University in 1982 majored in electromagnetic fields and microwave engineering. Since 1983, he joined the Radio Communication Lab. of ETRI, and has been working on the fields of radio signal processing, radio monitoring, and digital mobile communication. He is now Director of Radio Science Department, and is involved in development of radio resource utilization, radio part of FPLMTS, and terrestrial digital broadcasting systems.