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3G Mobile-Phone Technologies Edition

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Changes for the Better

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●Vol. 102/June 2003 Mitsubishi Electric **ADVANCE**

3G Mobile-Phone Technologies Edition

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Cover Story

Our cover shows development concept models for third-generation mobile phones, which are intended to help their owners create a truly 21st century lifestyle for themselves.

In our continuously evolving digital-network based society, third-generation mobile-phone technology already enables people to make use of knowledge and information from all around the world. This will both encourage further business development and significantly enhance lifestyles.

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Overview

Technologies for Third-Generation Mobile Phones

*by Yoshifumi Ito**

The 21st century has opened up a new era of third-generation mobile phones with mobile-multimedia capability under the new IMT-2000 global standard. Videophones and high-speed data transmission are greatly enhancing the power of mobile communications and providing new applications for daily life. In Japan, a third-generation mobile-communication service using W-CDMA technology was launched by NTT DoCoMo in October 2001. This service is currently being expanded as FOMA.

Mitsubishi Electric Corporation recognized the importance of commonly accepted global standards for mobile-communication systems from the beginning of the IMT-2000 standardizations, and our research laboratories in Japan, Europe and the United States have been active participants in this work. Based on the "MISTY" encryption algorithm developed by the corporation in 1996, the standardized "KASUMI" encryption algorithm was developed in ETSI in 2000 for use in W-CDMA mobile phones. This special edition of *Advance* introduces major technologies developed within Mitsubishi Electric to design and implement W-CDMA mobile phones.

Mobile phones using W-CDMA technology feature many advantages, including high quality and high-speed transmission of information, but they are also bringing about new forms of mobile-phone utilization by providing mobile-videophone functions and combining conversation with Internet access and other forms of data communication. Under the slogan "Better Link to the Future," we are committed to contributing to richly enhanced lifestyles in the 21st century by our ongoing development of third-generation mobile-phone technologies. ❑

**Yoshifumi Ito is Executive Vice President and a Member of the Board of Mitsubishi Electric Corporation.*

W-CDMA Mobile Phone Baseband-Demodulation Technology

*by Takahisa Aoyagi and Takahiko Nakamura**

This article describes the structure and features of a baseband demodulator developed for the "FOMA" W-CDMA mobile phone (type D2101V). The demodulation function consists of three primary structural blocks: the searcher unit, the finger unit, and the decoder unit. The size of the circuitry and power consumption have been reduced by using interpolation processing to reduce the operating speed, shared hardware and time-division processing, etc.

The International Mobile Telecommunications 2000 (IMT -2000) third-generation mobile-phone system is expected to comfortably exceed the communications capacities provide by second-generation digital systems such as the personal digital cellular (PDC) system protocol. This makes it possible to handle high-speed communications for, say, video; both low-speed and high-speed communications can be accommodated efficiently. Progress is being made in international standardization within the International Telecommunication Union (ITU). W-CDMA is undergoing development even within IMT-2000 as a powerful communications protocol, and in 2001, NTT DoCoMo, Ltd., was the first in the world to market a third-generation system, known as FOMA.

Mitsubishi Electric Corporation has contributed to the standardization activities through the adoption of the KASUMI encryption algorithm in the 3rd Generation Partnership Project (3GPP) Standard. Our efforts have focused on the activities of the 3GPP, the standardization organization for W-CDMA. Also, since beginning W-CDMA mobile-phone development, we have been active in the development of demodulation units for W-CDMA[1]. These constitute a key technology for reducing power consumption and improving functionality. The corporation's proprietary RAKE reception method protocol has been incorporated into the integrated circuits. The direct-conversion method has also been adopted for packaging/insertion into FOMA-enabled video image-capable mobile phone (D2101V) from NTT DoCoMo. Fig. 1 shows a block diagram of the demodulation processing unit developed. This article describes the structure and features of the baseband demodulator, which is vital to the process of demodulation.

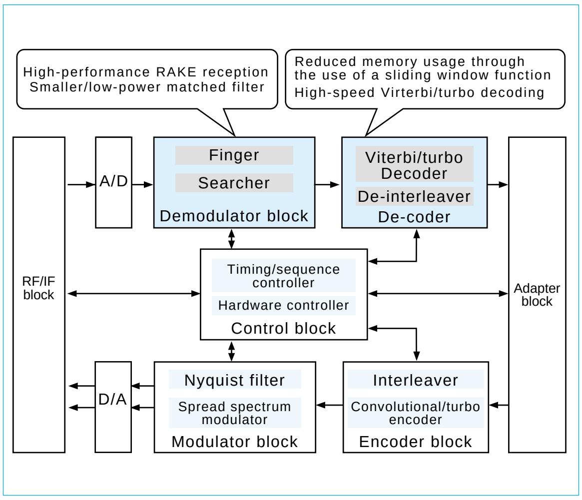

Fig. 1 Block diagram of the digital baseband processing unit

Structure of the Baseband Demodulator Unit

Table 1 shows the specifications of the baseband demodulator unit devloped. This demodulator is based on the 3GPP Standard, Release 99[2], and is compatible with a variety of physical channel formats, from 12.2kbps for voice through a maximum of 384kbps. The primary receiver functions are provided by the various blocks shown in Fig. 2. The primary blocks are the searcher block, which provides searcher functions (to ensure system synchronization) and multipath-detection functions (to measure a delay profile); a finger unit, which performs the RAKE reception by performing the despread function on the various multipaths and by performing coherent de-

Table 1 Specifications of the Baseband Demodulator

Standard	Based on the 3GPP Release 99 Standard
Wireless-access method	Direct sequence-code division multiple access frequency-division duplex
Chip rate	3.84Mcps
Multicode	Up to 3 codes
Information data rate	12.2 kbps to 384 kbps
Forward-error correction	Virterbi/turbo decoding
Reception diversity	RAKE combing (up to 8 fingers)

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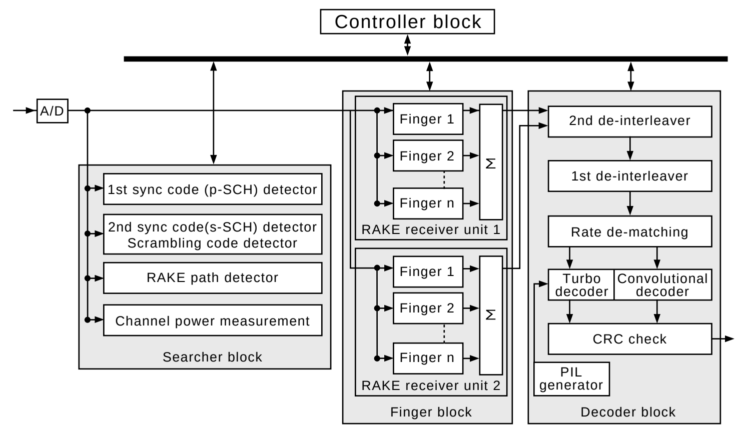

Fig. 2 Block diagram of the digital baseband demodulator

tection; and the decoder block, which performs high-speed Virterbi/turbo decoding. The features of these functional blocks are described below.

Searcher Block

The searcher block itself comprises the four sub-blocks shown in Fig. 2. These blocks are independent of each other, and perform cell searches and path-timing detection under operational control from the controller unit. The searcher block provides, primarily, the following functions:

* Detection of receivable frequency bands
* Cell searches that detect scrambling codes and timing
* Path-timing detection for RAKE reception
* Periodic level measurements for the detected cells.

The cell-search functions are also able to search for cells with a frequency deviation of greater than 6kHz prior to exerting automatic frequency control. In cell searches after automatic frequency control, the search time and power consumption are reduced by the simultaneous detection of multiple base stations.

In the path-timing measurements for the RAKE reception, multiple digital matched filters are provided in order to measure the delay profiles of multiple cells quickly, enabling stabilized reception even in soft handovers when the mobile phone is traveling at high speeds. The digital matched filtering provides a large reduction in power consumption through low-speed operations after checking the degradation due to aliasing and checking tolerable performance limits.

Finger Block

This enables RAKE reception by performing despread processing and coherent detection utilizing pilot symbols appropriate to the various delay paths detected by the searcher block. The finger block has multiple fingers that perform the coherent detection processes on each path, enabling RAKE-combining synthesis with a maximum of eight fingers. The finger unit also has two sets of RAKE receiver functions for data-channel and control-channel reception, so that data and control channels can be received simultaneously. Each finger can handle different base stations, enabling RAKE combining for up to four base stations in receiving data channels during soft handover.

The operations and functions of the block depend on the various specifications in the 3GPP standard[2], and RAKE reception is supported not only for dedicated physical channels but also for the common control channels such as the primary and secondary common-control physical channels, indicator channels such as acquisition indicator channels and paging indicator channels, and synchronization channels used in detecting transmission diversity types applied to the primary common control physical channel. In the dedicated physical channels, data reception up to a maximum of 384kbps is supported through triple multicode reception. For downlink transmit diversity, space-time transmit diversity, closed-loop mode 1, and closed-loop mode 2 are each supported.

The circuit scale and power consumption for the functions described above are kept to a bare minimum by the effective use of the interpolation method and shared circuitry (using time-multiplexed processing).

Channel Decoder Block

This performs the second de-interleaving and rate matching for each physical channel on the soft-decision signals input from the finger block. It also performs the first de-interleaving and error correction for each transport channel, and error detection using cyclic-redundancy checks

(CRCs). Convolutional decoding and turbo decoding are provided for error correction, and the error-correction processing uses the method specified by the digital-signal processor. In the convolutional decoding, a soft-decision Viterbi decoding process is performed, and turbo decoding is performed by iterative decoding using a soft-input/soft-output algorithm that uses a maximum a-posteriori probability (max-logMAP) algorithm. The benefits of this approach include the following:

1. Although, when performing turbo decoding using the max-logMAP algorithm, the forward or backward path-metric values must all be recorded at the point in time for the code length, the sliding window function makes it possible to reduce to one-third the memory capacity that must be provided in the turbo-decoder unit, reducing the memory region by storing only a portion of the path-metric values and decoding a part at a time.
2. A blind transport-format detection (BTFD) function has been added to infer the transport format that is transmitted, doing so based on error-detection results using Viterbi decoding that correspond to the variable rates when decoding the adaptive multi-rate (AMR) audio signal used in W-CDMA.
3. The following structures are used so as to have packet signals with transmission-time intervals (TTIs) equal to 20ms at 384kbps, AMR audio signals at 12.2kbps, and dedicated control channels (DCCH) processing at no more than 10ms:
   * The primary functions are hardwired, and the parameters such as the calculation settings are set by the DSP, providing both high speed and flexibility.
   * The turbo-decoding block and convolutional block can operate in parallel, making it possible to process multiple transport channels simultaneously.
4. Although performance is improved when the number of decoding iterations for turbo encoding is large, increasing the number of iterations increases power consumption, and so the number of decoding iterations is set by the digital-signal processor, increasing flexibility.

Characteristics

Fig. 3 shows typical performance characteristics obtained using a functional prototype based on the demodulation method described above. The figure shows the block-error rate characteristics given in the Case 1[3] environment defined in the 3GPP standard (i.e., a two-path model corresponding to 3km/h), and the results essentially match those from a computer simulation. The method developed in this research project obtained characteristics that satisfy the 3GPP standard under other conditions as well, and an IC containing the modulator and controller units has been created based on these prototyping results. This is used in the FOMA mobile phone (D2101V) made by NTT DoCoMo.

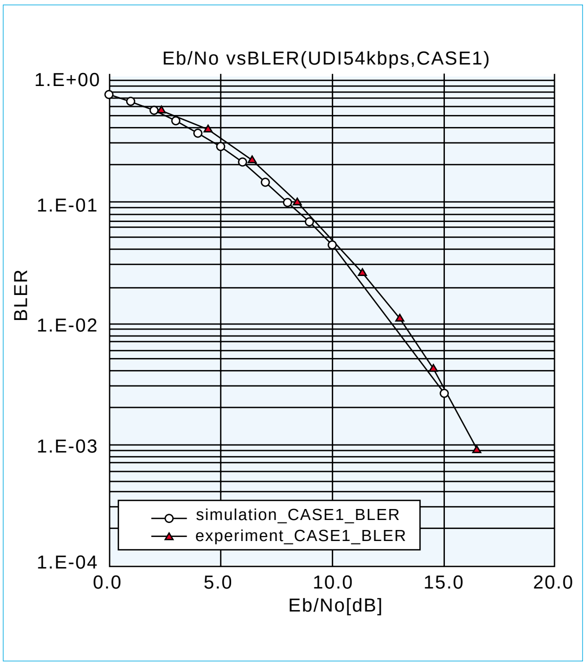

Fig. 3 Block error rate (BLER) of the prototype unit

The W-CDMA protocols are implemented by a confluence of multiple individual technologies, where most of these technologies do not, by themselves, provide optimal solutions for the transmission capacity of the system as a whole. Thus, in the development of modulation/demodulation technology in the future, it seems certain that system performance design, in particular, will become increasingly important. In addition, we anticipate the development of modulation/demodulation units for high-speed communications, such as high-speed downlink packet access (HSDPA), in addition to technologies for further miniaturization and power reductions, that are superior to those used in mobile phones for PDC systems. ❑

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W-CDMA Mobile-Phone Transceiver Devices

*by Eiji Taniguchi and Shintaro Shinjo**

Mitsubishi Electric Corporation has developed transceiver amplifiers for the broad dynamic range required by W-CDMA applications. An SiGe process has been used in low-noise amplifiers for receivers and driver amplifiers for transmitters with internal high-performance bias circuits, and a GaAs-pseudomorphic high electron-mobility transistor process has been used in the design of interstage matching circuits for high-power transmitter amplifiers that provide optimized source/load impedance. Both devices provide excellent performance.

Radio Frequency Component Circuit Structures

The radio frequency (RF) component circuit structures for a W-CDMA mobile phone are shown in Fig. 1. The receiver unit has a two-stage low-noise amplifier, integrated with a direct conversion mixer active element (a diode) in a SiGe monolithic microwave integrated circuit. In the transmitter unit, the driver amplifier is integrated with RF and intermediate-frequency (IF) variable-gain amplifiers, an up mixer, and a quadruple modulator in an SiGe monolithic microwave integrated circuit. The high-power amplifier uses a GaAs pseudomorphic high electron-mobility transistor to provide high-efficiency/low-distortion performance. Variable-gain amplifiers are used in the RF units and the IF units in order to provide a broad dynamic range. The low-noise amplifier, the driver amplifier, and the high-power amplifier were developed as described in this article. The circuit structures and performance of these amplifiers will be explained below.

LOW-NOISE AMPLIFIER. The low-noise amplifier used in W-CDMA generally requires not only a low noise figure, low DC current operation, and small size, but also high-saturation and low-distortion characteristics for transmit signal leakage. In this development project, high-saturation characteristics and low distortion were achieved while suppressing the quiescent current and minimizing degradation in the basic performance (i.e., the noise figure and the gain) through the application of a low-noise amplifier. This is based on an innovative dual-bias feed circuit in which the bias circuit is switched depending on the input signal level[1]. Fig. 2 shows the circuit structure of this innovative dual-bias feed-type low-noise amplifier. This amplifier has two different base-bias circuits for the resistor feed and the diode feed, where, when a small signal is inputted, the diode bias-feed circuit is essentially in an open state; on the other hand, when there is a large input signal, the diode bias-feed circuit operates as a constant-voltage source, producing low-noise, high-saturation, and low-distortion performance.

The results of prototyping using an SiGe process showed excellent performance in the dual

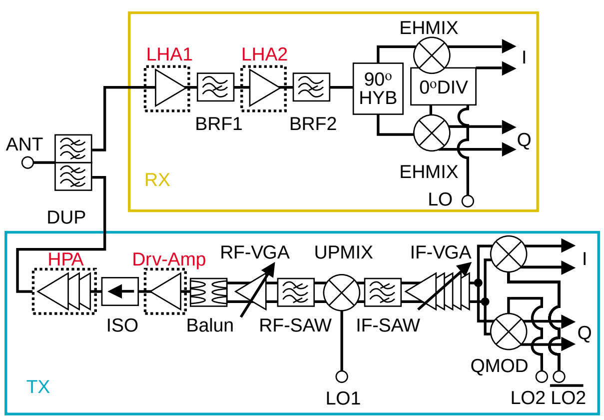

Fig. 1 Block diagram of RF section

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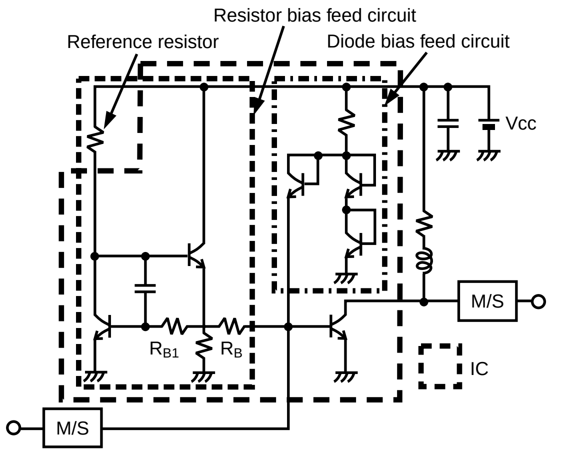


Fig. 2 Schematic diagram of dual-bias feed LNA

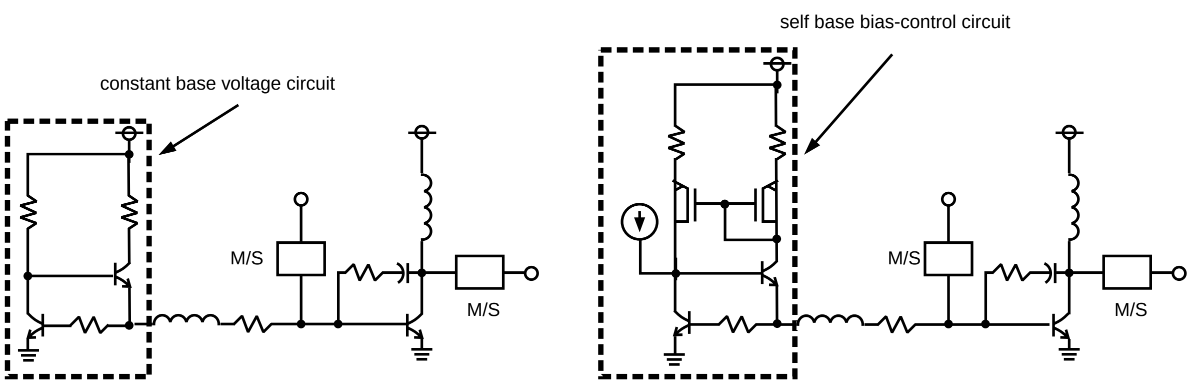
bias-feed low-noise amplifier, with a gain of 14.8dB, a noise figure of 2dB, an output 1dB compression point of 4.5dBm, and the third intercept point at 0.2dBm, at 6.1mA DC. Furthermore, for comparison, a conventional resistor bias feed-type low-noise amplifier, such as is commonly used, was fabricated using the same process technology. Comparisons confirmed not only that the DC current value and the small signal characteristics were about the same, but that the saturation characteristics and the distortion characteristics had been improved by more than 5dB.

DRIVER AMPLIFIER. Driver amplifiers must operate with a low quiescent current, must have less distortion than high-power amplifiers, and must be small in order to be made into monolithic microwave integrated circuits. Fig. 3 shows an equivalent circuit of the driver amplifier. In the figure, (a) is an equivalent circuit diagram of a conventional driver amplifier (Type A) with an internal constant-voltage bias circuit. The Type A driver amplifier does not supply an adequate base current when there is a high output power if the quiescent current is reduced, leading to poor performance in terms of distortion. Fig. 3 (b) is an equivalent circuit diagram of the innovative driver amplifier (Type B) with a self base bias-control circuit.[2] This latter circuit is structured from a combination of a p-metal oxide semiconductor field-effect transistor (FET) current-mirror circuit, in a constant-voltage bias circuit, and a constant-current source. The Type B driver amplifier makes it possible to supply automatically a current that is beyond the increase in the base current produced by the Type A driver amplifier at a high output power. Consequently, excellent distortion characteristics can be obtained even when operating with a low quiescent current.

The results of calculating the I/O characteristics of the Type B driver amplifier under the conditions of a 1.95GHz frequency and a 15.0mA quiescent current show an output 1dB compression-point improvement of 2.4dB over the Type A driver amplifier.

Furthermore, the Type B driver amplifier prototype had an output 1dB compression point of 15.0dBm and an operating current of 32.6mA. The application of the self base-bias control circuit demonstrated the ability to improve the distortion characteristics when operating with a low quiescent current.

HIGH-POWER AMPLIFIER. High-power amplifiers used in W-CDMA mobile phones must provide high efficiency while satisfying distortion requirements. In multistage high power amplifi-



(a) Driver amplifier with a constant base-voltage circuit (Type A)

(b) Driver amplifier with a self base bias-control circuit (Type B)

Fig. 3 Schematic diagram of driver amplifier

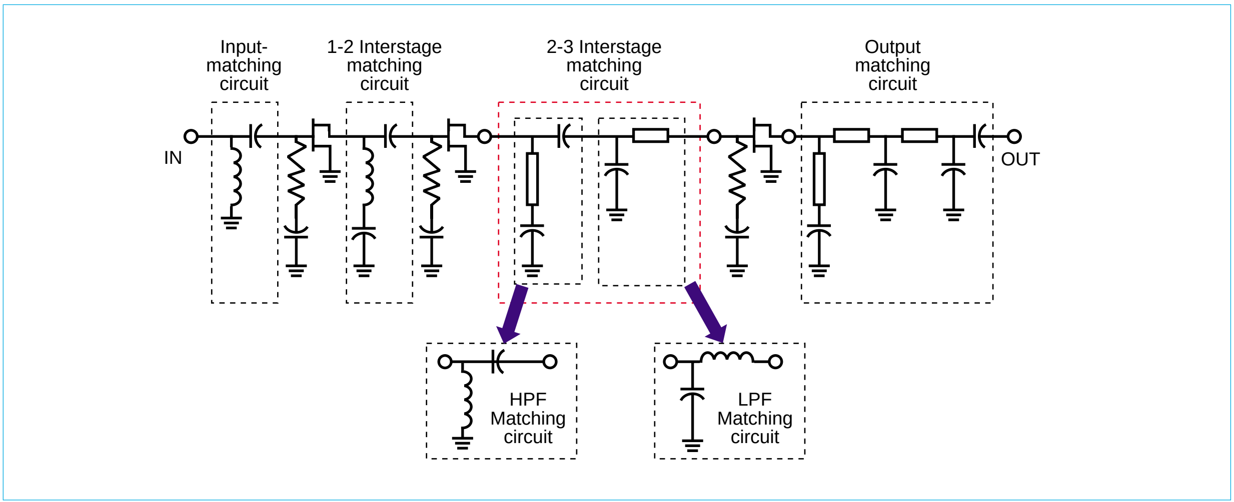


Fig. 4 Schematic diagram of the three-stage HPA module using the high pass filter/low pass filter combined interstage matching circuit developed in this development project

ers it is not only the FET in the final stage that operates with a large signal; the FET driving the final-stage FET operates at nearly the same signal strength. It is well known that the optimal source and load impedances for FETs when operating with small signals are different from those with large signals. Consequently, in order to ensure high efficiency while satisfying distortion requirements, it is necessary to research the structure of the inter-stage matching circuits and optimize impedances between stages.

Fig. 4 shows an equivalent circuit diagram of the prototype three-stage high-power amplifier module. A GaAs pseudomorphic high electron-mobility transistor process was used to obtain high efficiencies and low distortion in the amplifier elements. A high pass filter/low pass filter combined matching circuit was used between stages 2 and 3[3]. This high pass filter/low pass filter combined matching circuit makes it possible to ensure an optimal load impedance for the second stage FET while ensuring an optimal source impedance for the third stage FET given the W-CDMA specifications. Using a hybrid phase-shift keying modulated wave with a frequency of 1.95GHz and a chip rate of 3.84Mcps, the I/O characteristics of the three-stage high-power amplifier module developed were evaluated, indicating that a power-added efficiency of 43.9% with an output power of 27.1dBm was obtained with an adjacent channel leakage power ratio of -38.0dBc and a next adjacent channel leakage power ratio of -49.1dBc. It is evident that the use of the high-pass filter/low-pass filter combined-type interstage matching circuit makes it possible to obtain high efficiency characteristics while satisfying distortion requirements.

All of the circuit structures applied to the W-CDMA transceiver amplifiers in this development project are highly effective in communications systems requiring low power consumption and a wide dynamic range. They therefore promise to find wide utility in the next generation of mobile equipment. ❑

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W-CDMA Speech and Acoustic Processing Technology

*by Shinya Takahashi, Keiko Yoshida and Hitoshi Maruhashi**

In order to differentiate them from conventional mobile phones, W-CDMA mobile phones require excellent basic audio quality on a par with normal hard-wired telephones. When the videophone function-a unique feature of W-CDMA-is used in a hands-free phone mode, causing loud echoes and background noises to be picked up by the microphone, it is important to suppress these noises. Because of this, 3GPP has strict standards relating to speech and acoustic characteristics.

Speech and acoustic processing in W-CDMA mobile phones is performed by a digital signal processing unit, comprising a voice CODEC, an echo-cancellation unit, a noise suppresser, and an analog acoustic processing unit consisting of the receiver, the microphone, and the peripheral device structures. Excellence in both these technologies is imperative in providing users with the excellent audio quality that fulfills the 3GPP standard.

The noise suppresser developed at Mitsubishi Electric Corporation has superior capabilities, and was the first in the world to receive 3GPP endorsement as fulfilling all the required performance requirement standards. Overall superior speech and acoustic characteristics have been obtained by developing a high-quality receiver package approach that meets the frequency characteristic standards for 3GPP receivers, and an echo-cancellation unit with excellent performance.

This article describes the 3GPP speech and acoustic standards, and the processing technologies we developed to meet these standards.

Table 1 provides a summary of the adaptive multi-rate (AMR) method that is the 3GPP standard for speech CODECs, and a summary of the AMR-wide band (AMR-WB) version of it. Both methods can operate at variable bit rates for compatibility with different transmission capacities. The AMR method for the 12.2kbps bit rate used by most W-CDMA mobile phones in Japan has extremely high sound quality, approaching that of hard-wired phones. 3GPP has also standardized performance requirements for the frequency characteristics for analog audio systems and for AMR noise suppression.

Table 1 Specifications for the 3GPP Standard Speech CODEC

CODEC	AMR	AMR-WB
Bandwidth	300Hz ~ 3.4kHz	50Hz ~ 7kHz
Sampling frequency	8kHz	16kHz
Bitrate	12.2 ~ 4.75kbps 8 grades	23.85 ~ 6.6kbps 9 grades

When mobile phones are used in the hands-free mode, loud echoes reach the microphone from the speaker. Although a subtractive method is used to suppress these echoes (in which the echoes are inferred through adaptive filtering), because the echoes include non-linear components generated within the audio section, adaptive filtering alone is often unable to suppress the echoes completely. The corporation has therefore introduced technology that attenuates the residual echo period without producing an audibly odd sound quality by controlling frequency characteristics. In addition, a delayed detection method is used to perform high performance double-talk detection guarding against incorrect echo inferences when there is double talk (i.e., when individuals on both the transmitter side and receiver side speak simultaneously).[1]

Noise Suppresser

A PROPRIETARY NOISE-SUPPRESSION METHOD. Noise suppression (NS) requires substantial sup-

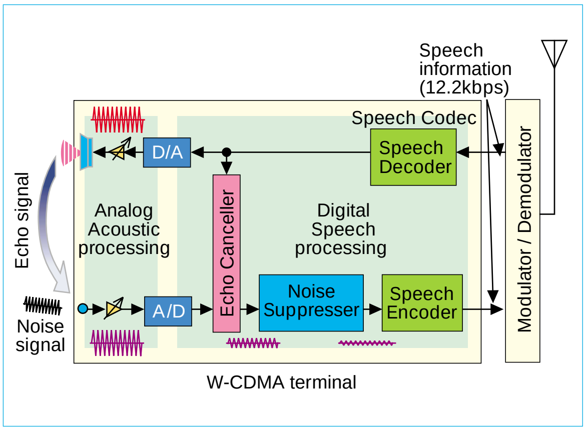

Fig.1 Block diagram of the W-CDMA mobile phone

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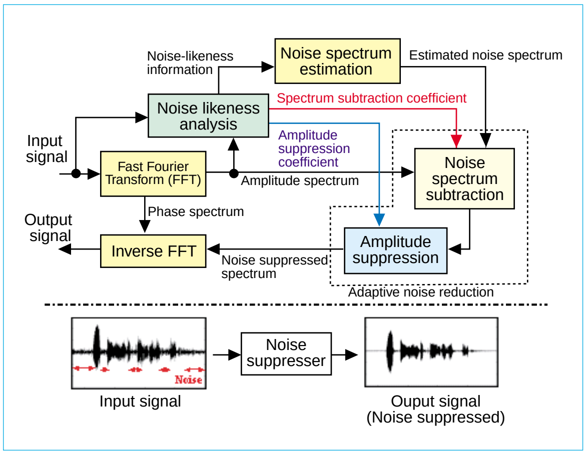

Fig. 2 Block diagram of the noise suppresser

pression of the background noise only, without degrading the speech signal. Fig. 2 shows a block diagram of the NS method developed at Mitsubishi Electric. This method is based on spectral subtraction where the spectrum that is primarily noise is subtracted in the low frequency domain where the signal-to-noise ratio (SNR) is high, thereby reducing the amount of noise, while attenuating the spectrum that is largely noise in the high-frequency domain where the SNR is low. This method, which suppresses noise while preserving the speech spectrum, gives excellent noise reduction.

3GPP EVALUATION AND TEST RESULTS. In 3GPP, the performance requirements for noise suppression are specified in TS26.077. Methods that fulfill all of the performance requirements in subjective evaluations and objective evaluations by third-party testing laboratories are granted 3GPP endorsement. Not only have the noise-suppression technologies developed by the corporation fulfilled all of these performance requirements (a total of 74 different requirements) in subjective testing by third-party laboratories in two different languages (Japanese and English), but they have also fulfilled the performance requirements in objective evaluations.[2] The result is that, in May 2002, this Mitsubishi noise suppression was the first in the world to receive 3GPP endorsement. Fig. 3 shows some selected results of the subjective evaluation results regarding the amount of improvement provided through the use of this noise suppression.

Acoustic Design

RECEIVING FREQUENCY CHARACTERISTIC STANDARDS IN 3GPP. In 3GPP, the standards for the acoustic characteristics of the terminal device are covered in TS26.131, which incorporate some Mitsubishi Electric proposals.[3] The distinguishing features of the various standards are that they were established based on the premise that the acoustic measurements of the terminal equipment would be done under conditions that are extremely near to those of actual use, using, for example, an artificial ear that takes into account the leakage that is present in a real ear. Fig. 4 shows the frequency characteristics masking pattern (the boundaries showing the upper and lower limits on the frequency characteristics for phone communications) of the receiver during handset conversation in these specifications. In line with our proposal, the upper limit in the low frequency band (up to 100Hz) was relaxed in anticipation of the implementation of the wide-band CODEC, AMR-WB.

W-CDMA MOBILE-PHONE AUDIO DESIGN. In the design process for the structure of the casing that contains the receiver audio system in the FOMA™ D2101V, we were able to perform the design work

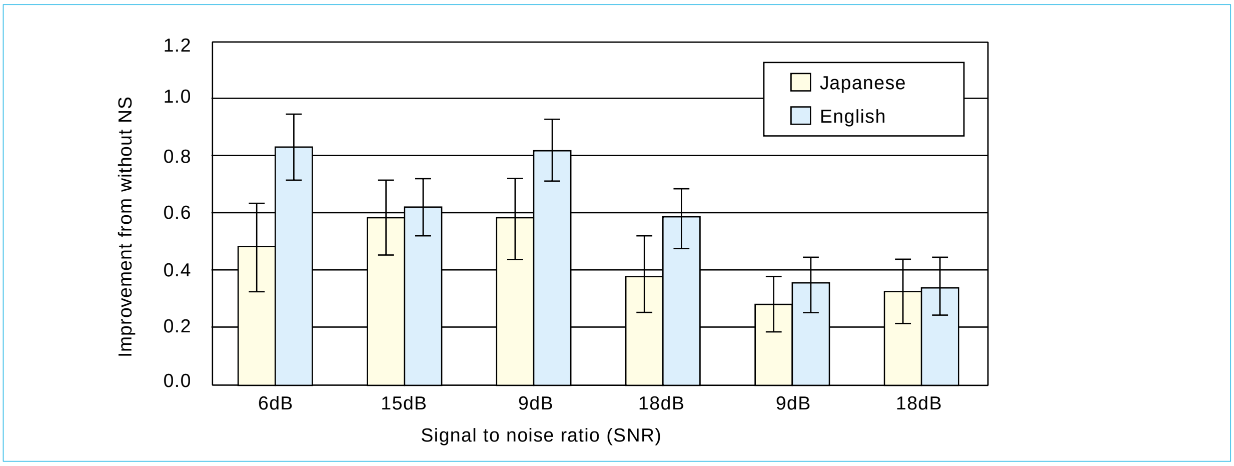

Fig. 3 Selected objective evaluation results

efficiently by adopting proprietary audio-design simulation techniques that take into account, for example, the effects of leakage between the user's ear and the ear-piece or the surrounding mechanical structures within the receiver unit. Mitsubishi Electric was the first to apply to domestic (Japanese) mobile phones a low acoustic impedance implementation that makes it possible to maintain consistently stable low-frequency characteristics even under varying coupling conditions, thereby producing high-quality performance meeting the TS26.131 standard, see Fig. 4.

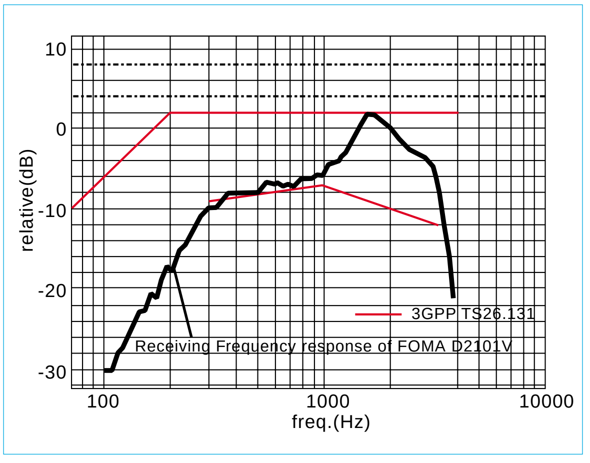

Fig. 4 Receiving frequency response for the TS26.131 and the FOMA D2101V

Users will only welcome the sophisticated functions made possible by W-CDMA mobile phones if, at the same time, the very highest audio quality is maintained in speech, free from the distractions caused by noisy operating environments and “hands-free” operation. Mitsubishi Electric not only helped to develop the standards necessary to ensure this, but also stands in the forefront of efforts to incorporate these standards in small, reliable and efficient devices. ❑

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W-CDMA Mobile-Phone Video Coding and Transmission Technology

*by Fuminobu Ogawa and Shin-ichi Kuroda**

This article describes the 3G-324M standard and its implementation in enabling videophone functions using W-CDMA mobile phones. Through a hybrid structure of software for digital signal processing combined with proprietary hardware, a single IC module has been enabled to handle video decoding, multiplexing/demultiplexing for multimedia communication, and control for multimedia communication. At the same time, the technology has enabled a high degree of error resiliency while reducing the wait time before communications can be started.

Protocol Stack for Videophones

Videophone functions for W-CDMA mobile phones follow the 3G-324M multimedia telephony standard established by the 3rd Generation Partnership Project (3GPP). Conformance to the 3G-324M standard ensures cross-connectivity with the terminal equipment made by other companies. Fig. 1 shows the 3G-324M protocol stack. ITU-T H.263 is mandatory as the video codec, and ISO MPEG-4 visual Simple Profile Level 0 (SP@L0) can also be used. The 3GPP-AMR is mandatory for the audio codec, and the ITU-T H.245 standard is used for the multimedia communications control that, for example, exchanges capability information between the terminals. ITU-T H.223 is used for multiplexing the various media, such as video, audio, and data. In addition, numbered simple retransmission protocol (NSRP) frames and a control-channel segmentation and reassembly layer (CCSRL) are used to ensure accurate transmission of the H.245 messages, even in an error-prone environment.

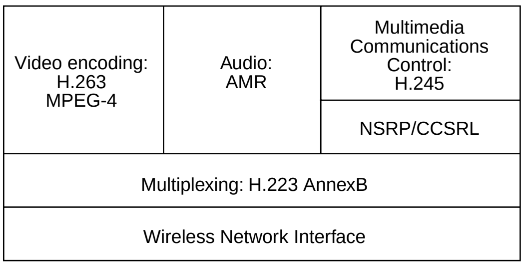

Fig. 1 Protocol stack for 3G-324M multimedia system video encoding: H.263 MPEG-4

Video Encoding

In the 3G-324M standard, the MPEG-4 visual SP@L0 can be used. In MPEG-4 SP@L0, images of the maximum QCIF size (176 pixels x 144 lines) must be decoded at 15 frames/second.

MPEG-4 has an error-resiliency function that prevents the image quality from degrading even when there are transmission errors. The use of functions such as resynchronization markers to enable rapid recovery when an error has occurred, data partitioning to prevent the propagation of errors into the image data, and reversible variable-length code (RVLC) to reassemble from the opposite directions words in which there were errors, makes it possible to prevent degradation of the playback image. This is achieved even in environments with a random error rate of 10^{-4} and a burst error rate of 10^{-3}. Fig. 2 shows typical decoding results for encoded video data to which a random error (BER=10^{-4}) has been applied.

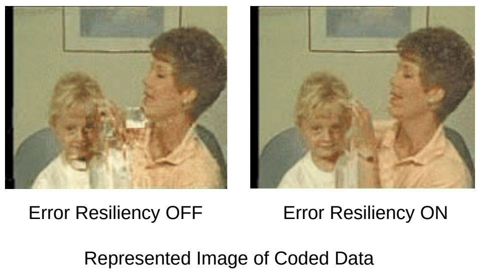

Fig. 2 Represented image of coded data

MPEG-4 standardizes a deblocking filter that reduces encoding noise, which tends to appear at block boundaries. The deblocking filter is highly calculation-intensive, and accounts for more than half of the decoding process, and it is therefore necessary to find a way of reducing the calculation overhead without compromising quality.

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Multiplexing/Demultiplexing for Multimedia Communications

In the 3G-324M standard, multiple media, such as video and audio, are multiplexed into a single data stream, and transmitted according to the multimedia multiplexing procedures standardized in ITU-T recommendation H.223. This recommendation establishes a multiplexing method with a two-layer structure comprising an adaptation layer (AL) that performs framing depending on the characteristics of each media type, and a multiplexing layer (MUX) that mixes the media and does the framing depending on the characteristics of the transmission path. Fig. 3 shows an example of multimedia multiplexing according to H.223. H.223 stipulates different types of ALs tailored for each set of media characteristics, and different levels of MUXs with different error resilience. Combining appropriate H.223 ALs and MUXs enables multimedia communications for a wide range of applications. In the 3G-324M standard, MUX Level 2 is applicable in view of the level of transmission errors, and the type of AL is selected with respect to the transmission delays.

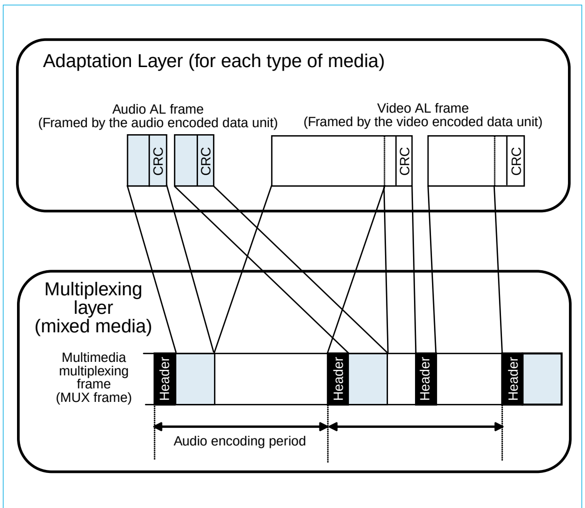

Fig. 3 Multiplex Format in H.223

Transmission error has a large impact on the quality of communications in mobile networks. The frame length for multiplexing should be short to enable rapid recovery when an error has occurred. On the other hand, because overhead such as the various types of headers, the CRC, etc., also has a large impact on the multiplexing efficiency, the frame lengths should be as long as possible. Given these conflicting requirements, the multiplexing efficiency can be improved through innovations such as dynamically and adaptively changing the frame length.

Control for multimedia communication

In multimedia communications combining audio, video, and other media, parameters including media type used and the encoding method must be selected appropriately for the terminal capability. The multimedia communications control functions are used, e.g., to exchange capability information between terminals. These multimedia communications control functions include capabilities negotiation and logical-channel signalling to determine the media types, encoding and transmission methods to be used, along with commands and indications carrying multimedia synchronization information. In 3G-324M-standard terminal equipment, the multimedia communications control method used is a general-use protocol based on ITU-T Recommendation H.245. H.245 is used in a variety of applications, such as B-ISDN, LANs, and mobile communications, and has a wide variety of communications control functions. Assuming it is used in an error-free environment, H.245 enables reliable control using in-channel request-response messaging.

To ensure the correct transmission of the H.245 messages, the underlying layer provides the error-free environment. The NSRP frames, shown in Fig 1, add error-detection information to the data. On the receiver side, the transmission is only acknowledged when the data has been received correctly. Error-free states are ensured by sequential data transmission at the sending side. In addition, the data is segmented at the control channel segmentation and reassembly layer (CCSRL) to reduce the packet error rate.

Before the start of communications, the number of H.245 messages exchanged between the terminal equipment amounts to between 10 and 20. Each message is sent sequentially after waiting for the transmission acknowledgement. When there is a transmission delay of several hundred milliseconds in the W-CDMA network, there will be a wait time of about ten seconds before communication begins. This wait time is reduced by cancatenating multiple H.245 messages together into each transmission frame. Concatenating many messages together can reduce the transmission time, but may involve the delay caused by linking the messages after waiting for many of them to be generated. Furthermore, message concatenation lengthens the packet, increasing the error rate. Concatenating the H.245 messages adaptively so that message concatenation causes neither longer delays nor higher error rates makes it possible to reduce the wait time before the commencement of communications by about 50 ~ 70%.

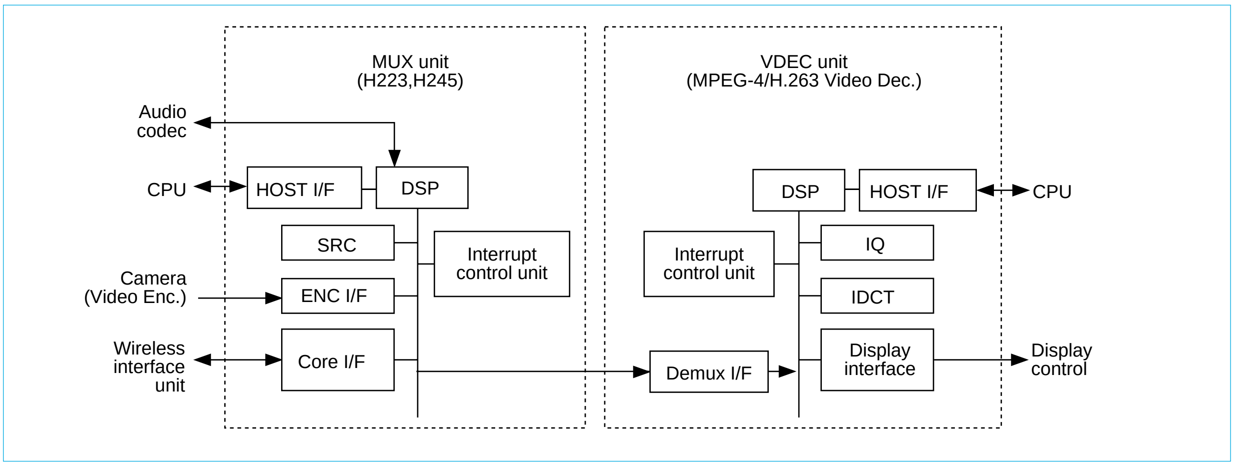

Fig. 4 Block diagram of the 3G-324M IC module

3G-324M-Compatible IC Module

A 3G-324M-compatible IC module has been developed to produce MPEG-4 video communications equipment such as videophones, image content players, and similar devices. The primary functions of this module are MPEG-4 video decoding, H.223 media multiplexing/demultiplexing, and H.245 control for multimedia communication. The MPEG-4 video encoding is performed at the camera unit. The video encoding unit and the audio codec are separate from the module; the data flow is switched using a wireless interface unit when there is a videophone rather than speech communications alone, and both the power supply and the clock are supplied according to the operation mode under the control of the host CPU. This makes it possible to reduce power consumption during voice communications and during playback of locally stored video.

As is shown in Fig. 4, the module comprises a VDEC unit that performs the MPEG-4 video decoding, and a MUX unit that performs the multimedia multiplexing/demultiplexing and the multimedia communications control. Both of these units use a hybrid structure with a general-purpose DSP and proprietary acceleration hardware from Mitsubishi Electric Corporation, with both the flexibility and upgradability provided by DSP software processes and the high-speed processing provided by hardware processes.

Table 1 shows the features of this IC module. The size of the circuit is 245K gates (including the DSP core) in the logic unit, and 3.2Mbit (including the on-board DSP memory) in the on-board memory unit. It uses a 0.18micron CMOS wafer process to achieve a power consumption of 69mW when performing MPEG-4 QCIF 15 frame/second video decoding and multimedia multiplexing/demultiplexing processes.

Table 1. Features of the 3G-324M IC Module

Video decoding	Encoding method	MPEG-4 simple profile level 0 H.263
	Image size	QCIF (176 x 144 pixels) SQCIF (128 x 96 pixels)
	Decoding performance	Bit rate: max. 64Kbps Frame rate: max. 15fps
Multiplexing method		H.223 AnnexB
AV communications control		H.245
Size of circuits	Logic circuits	245K gates
	Memory	3.2Mbit
Power consumption		69mW (at 48MHz, internal voltage 1.8V)

The article has discussed techniques for enabling two-way multimedia communications in the W-CDMA environment. A videophone multipoint connection service was launched on October 1, 2002, and the videophone services in the mobile-phone environment are anticipated to go beyond merely "chatting" to include a broad variety of developments such as remote monitoring, education, contents distribution, etc. ❑

W-CDMA Mobile-Phone Data-Security Technology

*by Tetsuo Nakakawaji, Mitsuru Matsui and Takeshi Chikazawa**

The article describes the security technologies required in the W-CDMA mobile phone system, including wireless communications-level security functions, data-communications level security functions, and contents-level security functions.

Wireless Communications-level Security Authentication.
This is a technology for authenticating that the user has the authority to use the wireless communications, or, in other words, that the user is the subscriber for whom the communications charges have been paid. When a call is requested, the network side authenticates the mobile phone based on the subscriber information in the handset. If the subscriber information were sent to the network side in the plain-text mode, it would be possible for an eavesdropper to steal the subscriber information and successfully impersonate the subscriber. Authentication is therefore performed by both sides performing calculations using the subscriber information and comparing the results. In W-CDMA, there are functions f1 to f5 defined as those by which the calculations are to be performed. The algorithms within these functions are not subject to standardization, but rather are determined by the operators.
Note: *In the process by which the calculations for authentication are performed, the mobile phones and networks share the authentication keys and the illegal data-modification prevention keys.*

DATA AUTHENTICATION. In W-CDMA, function f8 is used to generate a series of random numbers, and exclusive logical OR sums are performed for each bit of the user data and signal data to perform the encoding, see Fig. 2. The bit length for encoding/decoding, the up/down link, the counter, the logical channel identifier, and the key for data confidentiality are input to the logic function f8 to generate the sequences of random numbers.

DATA INTEGRITY. This refers to the technology in which authentication codes are added to the signal data in wireless communications in order to detect unauthorized data modification. It is also known as message authentication. Function f9 is used to generate the authentication code (see Fig. 3) to be added to the data in order to check for unauthorized data modification and ensure data integrity. The data, the up/down link, a counter, a random number for each user, and the integrity key are input to function f9 to generate the message-authentication code. The receiver compares the message-authentication code sent by the sender to the message-authentication code generated by the receiver, making it possible to confirm, when the codes match, that there has been no illegal data modification.

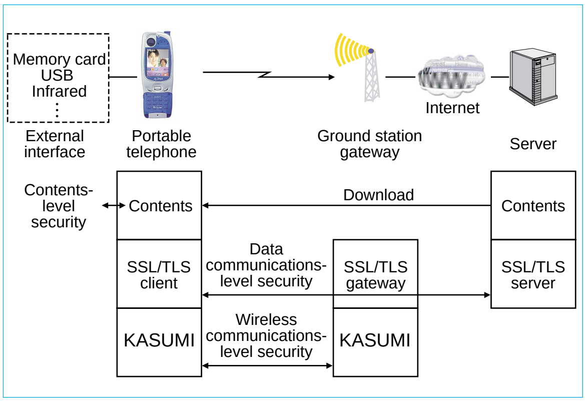

Fig. 1 W-CDMA mobile mobile-phone data security technology

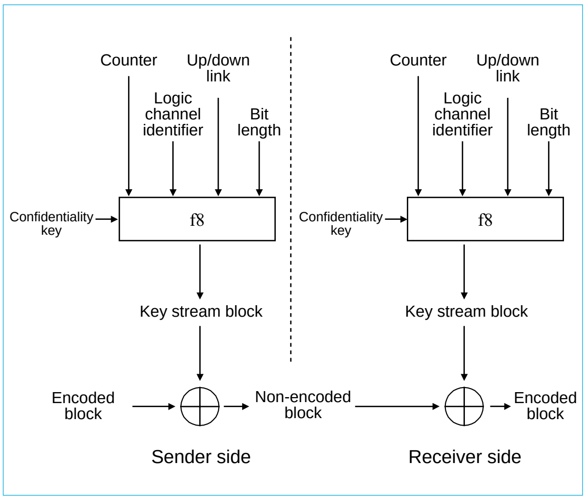

Fig. 2 Function f8 to insure data confidentiality

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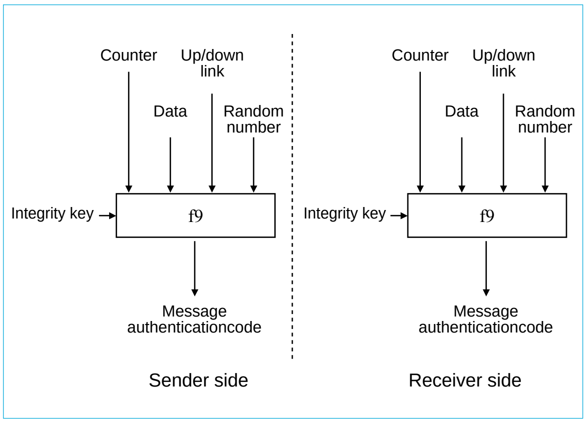

Fig. 3 Function f9 to insure data integrity

ENCRYPTION ALGORITHM KASUMI. The encryption algorithm that forms the core of the data-confidentiality function f8 and the data-integrity function f9 is known as KASUMI.

The following conditions to be fulfilled when developing an encryption algorithm were defined by the Third Generation Partnership Project (3GPP) consortium, which is researching technical standards for W-CDMA:

* Security must be preserved under open specifications.
* Packaging restrictions in mobile phones mean that the algorithm must be implemented in hardware using no more than 10K gates.
* W-CDMA traffic considerations mean that processing must be at 2Mbps.

Because there was only a six-month lead time available to develop the encryption algorithm, it was decided to work on an existing encryption algorithm rather than to develop a new algorithm from scratch. A search for existing encryption algorithms fulfilling the requirements described above showed that the only one available was the MISTY[1] algorithm at Mitsubishi Electric Corporation; KASUMI was developed based on reworking the MISTY algorithm.

Data-Communications Level Security

Authentication and confidential communications for wireless telephones generally use the SSL/TLS (Secure Socket Layer/Transport Layer Security) that has become the global standard for security protocols between web servers and browsers on the Internet. However, not all SSL/TLS functions are implemented in mobile phones: the specifications are a subset of SSL/TLS.

There must also be a security function to guarantee the legitimacy of the various contents and modules downloaded from the network. Here "legitimacy" refers to the data having been generated by the correct provider and not having been illegally modified after it was generated, and refers to a function on the mobile handset side to verify and confirm legitimacy. The technology by which legitimacy is ensured uses a system whereby the server side applies a digital signature to the data, and the signature is validated on the mobile phone downloading it, thus confirming the legitimacy.

Contents-Level Security

Research into contents-level security is still at an early stage, and standards have yet to be established. An external memory card that is inserted into the mobile phone has been developed at Mitsubishi Electric as a copyright-control technology.[2] The technology is enabled through encapsulation using encryption technology.

When the encapsulated contents are stored externally, they are encrypted with information that is specific to the mobile phone. Similarly, when the contents are played back, the contents are decrypted using the same data, unique to the mobile phone. This makes it possible to restrict the playback of contents to the mobile phone on which they are stored.

The security of communications for the third generation of mobile phones is critically important for their widespread adoption. Mitsubishi Electric is at the forefront of successful efforts to ensure the very highest degree of security at every level. ❑

References

[1] Matsui, et. al.: "Block encryption algorithm 'MISTY'," Mitsubishi Denki Giho, Vol. 72, No. 5 (1998) (in Japanese)

[2] Miyazaki, et. al.: "Digital contents distribution system using a memory card," Mitsubishi Denki Giho, Vol. 76, No. 4 (2002) (in Japanese)

W-CDMA Mobile-Phone Software Technology

*by Tomo-oki Ukiana and Yoshiaki Katayama**

A mobile-phone software platform known as cellular integrated communicator architecture (CINCIA) has been developed. CINCIA is a hybrid-structure software platform equipped with a real-time kernel based on the μITRON standard, and a dynamic kernel that controls the application. It has a three-layer hierarchical structure and modular architecture, providing a high degree of scalability and reusability.

CINCIA Mobile-Phone Software Platform

W-CDMA mobile phones are compatible with a large variety of data and video services, in addition to providing audio and data communications services. Because of this, the application software provided with them must have more sophisticated functions, and is larger, than conventional embedded system software. This increases the amount of work involved in development and test activities, making it difficult to develop the required functions and perform quality assurance within limited development lead times. The CINCIA mobile-phone software platform was developed to improve the productivity of software development so as to resolve the above issues.

CINCIA has a modular architecture and a hierarchical structure, comprising three layers: an application layer, a library layer, and a hardware-abstraction layer (HAL). With this, and the segmentation of software into modules, CINCIA provides excellent scalability and reusability, see Fig. 1. W-CDMA mobile phones for which CINCIA is applicable comprise over 170 modules, and these are packaged for implementation within 7MB of ROM and 3MB of RAM. The various functions are introduced below.

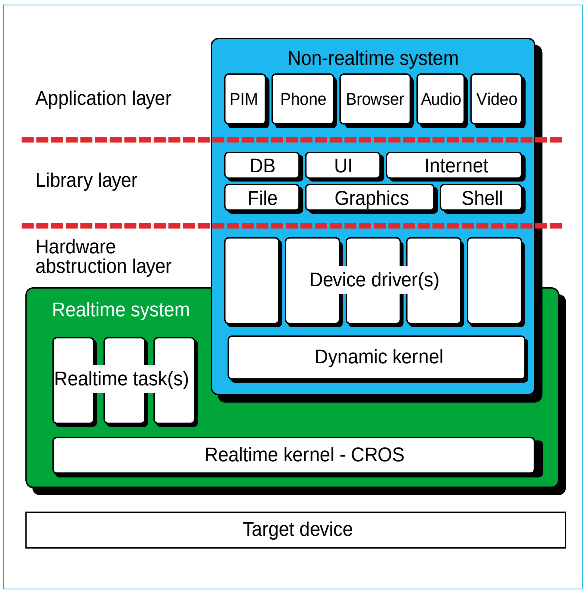

Fig. 1 Mobile-phone software platform CINCIA

HAL

HAL, the lowest layer, conceals any differences in hardware in the individual equipment types from the software at higher layers, ensuring portability of the software as a whole. Because the real-time performance will vary for each software module, the kernel is a hybrid OS equipped with a real-time kernel known as a configurable real-time operating system (CROS), based on the μITRON standard for controlling real-time tasks, and also equipped with a dynamic kernel that adjusts thread priorities dynamically in order to control applications, enabling the complex scheduling required by mobile systems. Not only are the basic OS functions such as memory/timer management, semaphore and messaging provided, but also power-saving functions, memory-protection functions and other extended functions required in mobile terminals. The use of the μITRON standard, a Japanese industrial standard for embedded systems, makes it possible to use existing software developed both within the corporation and elsewhere. It also facilitates development lead-time reductions by making it easier to train engineers.

Library Layer

The library layer, the intermediate layer, provides a variety of services to the higher-level applications. The library, which provides the CINCIA, is device independent, making it usable across a wide variety of mobile phones. Concentrating the functions in the library makes it easy to respond to new applications and additional products, and makes it possible to limit the amount of software that needs to be developed for each type. Furthermore, the various library interfaces are designed in accordance with

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industrial standards wherever possible, simplifying the development of applications that use the various types of services supplied by the library. The primary library functions are described below.

The file system has interfaces by which applications can acquire standardized access to the ROM, RAM, flash memory, removable media, and other types of storage devices, and has database functions and registry functions, among others.

The graphics system has low-level graphic interfaces with an off-screen sprite model and user interface (UI) components enabling customization of the look and feel for each type of equipment.

The telephony system supplies functions compatible with voice communications and a variety of network services.

For the Internet, high-level communications protocols such as TCP/IP and SSL are provided, along with basic functions such as character-set control, along with functions for handling messaging services.

The shell controls the launching and termination of applications, the screen order of the applications that are running, and event delivery.

Application Layer

The application layer, the highest level, includes a variety of applications such as a phone book, a browser, etc. The UI module of these applications can provide new functions more easily, and provides for development and customizing for each type. In CINCIA, this is handled by providing software development tools that increase the efficiency of development and testing of the mobile-phone application UI module.

The article has described the approach taken in structuring the CINCIA mobile-phone software platform. The technologies described in this article have already been applied to the development of W-CDMA mobile phones. In the future, as there are software enhancements for new functions, and as a variety of development support systems are provided and improved, the development of high-functionality/high-quality software will be carried out with even higher levels of efficiency. ❑

Mobile-Phone Structural Design Technology

*by Shiro Takada and Atsushi Musha**

W-CDMA mobile phones must be light and highly reliable, and from the perspective of structural-design technology development, drop-impact and heat-dissipation technologies are critical. This article provides an overview of technology development focusing on validation through analytical techniques able to forecast drop-impact characteristics and temperature profiles at the design stage, and technology development focusing on model experiments. It also describes the application of these techniques to W-CDMA devices.

Development of Drop-Impact Design Technologies

The ability to withstand the shock of impact is important in ensuring reliability in the environments in which mobile phones are used. At Mitsubishi Electric Corporation, drop-impact analytical technologies are being developed to forecast quantitatively, in the early stages of design, the response of equipment to physical impacts. This makes it possible to develop appropriate structures. The article describes both the drop-impact simulation technologies being developed and their application to W-CDMA mobile phones.

A drop-testing machine with a sloping slide system, as shown in Fig. 1, has been developed in order to quantify the shock experienced by devices after freefall. This test equipment is constructed so that a test sample is dropped while held in a test jig in which the holder releases the test sample immediately before it strikes the floor. As a result, the orientation with which the test sample is dropped is controlled until immediately before impact, making it possible to reproduce "freefall" consistently. This test equipment makes it possible to measure the impact load, acceleration and strain during the contact, and the velocity of the test sample immediately before impact.

Straight-type mobile-phone drop-impact analysis is described next. In the modeling, the main components of the chassis are assembled from a front and rear case, and the efficiency of the analysis is increased by using a fine-element mesh in the vicinity of the impact, and a coarse-element mesh elsewhere. In addition, a printed-circuit board, a shield casing, a liquid-crystal display component, a battery, an I/O connector, and other critical components were modeled as internal parts. With the top of the antenna as the part making the impact, the drop impact analysis was performed for a freefall to a rigid floor from a height of 1.5 meters (with an impact velocity of 5.4m/s).

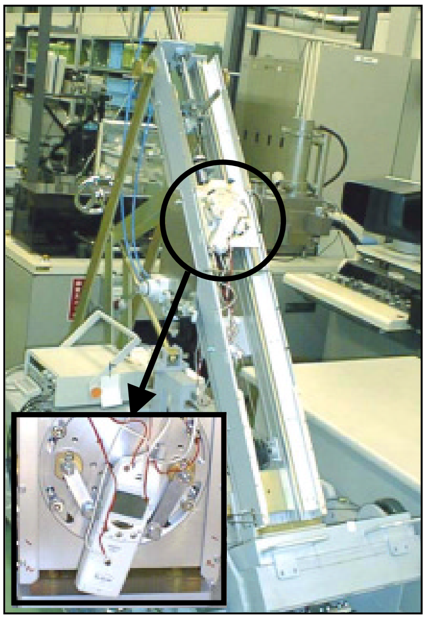

Fig. 1 Drop-testing machine with sloping slide system

Fig. 2 shows the results of the above analysis, with the experimental results of an analysis of the time-history waveform of the drop-impact load as measured by the drop-testing machine with the sloping slide system under the same conditions. Not only does the shape of the graph of the impact load *vs.* time show the reproducibility of the test, but it also validates the analytical model because it is in close conformity with the predictions.

The results of applying this drop-impact simulation technology to the early stages of W-CDMA mobile-phone chassis design are as follows. In such devices, a magnesium alloy is used for the

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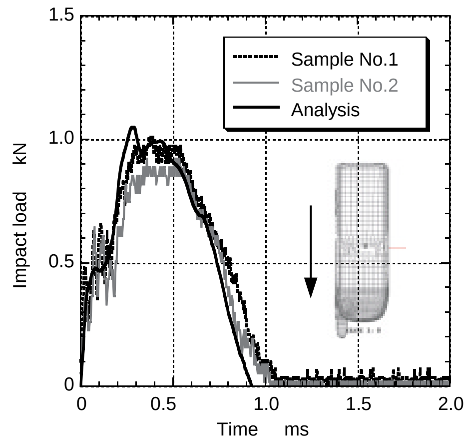

Fig. 2 Time history waveform of impact load

front case in order to ensure rigidity, and a polymer is used for the rear case. It has been shown clearly and quantitatively that the impact load when dropped is greater than it was in the all-polymer chassis of the past. Additionally, simulation technology was used to make structural improvements such as the optimization of the chassis fit, the locations of the fitting attachments, internal reinforcement ribs, etc., as well as improvements in the shape of the antenna and in the structure surrounding the camera mount.

The typical optimization of an antenna structure is described below. Fig. 3 shows the analytical model used at the early stages of the W-CDMA device chassis-design process, with the stress distribution indicated by the analysis.

When dropped from the antenna side, the stresses produced in the magnesium chassis vary greatly depending on the shape of the top of the antenna, so the shape of the antenna was optmized. The reinforcing ribs were also optimized to reduce the strresses that occur around the place to which the antenna is attached.

Development of Heat-Dissipation Design Technologies

It is difficult to estimate increases in temperatures in electronic components and on the surfaces of the device chassis in electronic devices such as mobile phones because the thermal generation profiles are non-uniform. Thus, the use of numerical simulation technologies is more effective. A description of the thermal analysis used in the development of W-CDMA mobile phones follows.

Mobile phones, as shown in Fig. 4, are made from a printed-circuit board on which the electronic components are mounted, a shielding case that covers the transceiver circuits, a liquid-crystal module, a battery, a speaker, a receiver, a microphone, keys, and a variety of other components. These items are housed in a chassis. The primary heat sources are the electronic components on the printed-circuit board, where the heat generated is conducted to the mounted components and air gaps, ultimately to escape to the ambient air through the convective air flow against the surface of the chassis and through radiation from the chassis. Note that the components are tightly packed inside the mobile phone, and thus the effect of heat transfer through natural convection is minimal, and

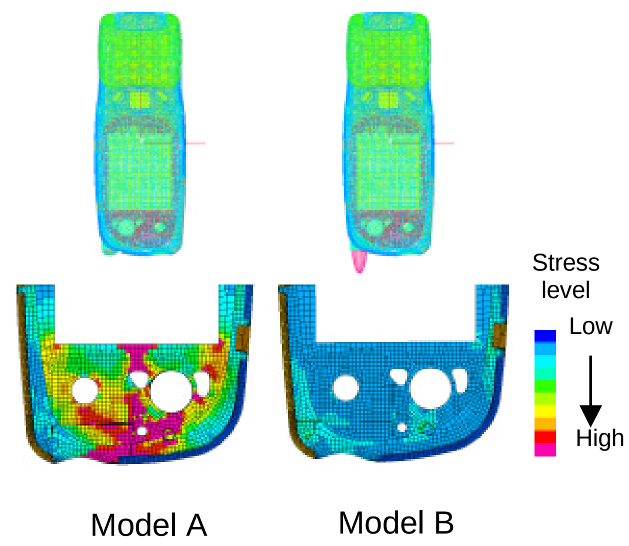

Fig. 3 Stress distribution around the top of the Mg chassis

the effects of thermal radiation are also small when compared with thermal conductance. As a result, evaluations were performed taking only thermal conductance into account.

Finite-element analysis was used as the numerical technique required in the design. An average value for the heat-transfer coefficient determined experimentally for convection to the air and thermal radiation from the surface of the chassis was used. Furthermore, measurements were made of thermal conductance for the multiple compound components in the structure, such as the printed circuit board, and the model was simplified by using these individual components assumed to be made of anisotropic materials.

Experimental equipment with simulated heat generation was used in which the conditions of thermal generation could be set explicitly for a structure in which dummy elements, copper plates, and heaters were stacked on a printed-circuit board. This was used to perform validation experiments. The temperature measurements were performed for the surface temperature of the mounted components from the front case through to the rear case on the central axis of the dummy thermal-generation elements, as shown by the dotted line in Fig. 4.

Fig. 5 shows the experimentally-derived and analytically-derived thermal distributions. The solid line shows the experimental values and the dotted line the analytical values. In the figure, (a), (b), (c), and (d) show the measurement points (a), (b), (c), and (d) on the component surfaces in Fig. 4. Fig. 5 shows the excellent agreement between the analytical and experimental values for the temperatures on the surface of the chassis, and that it is possible to estimate accurately the temperatures in the actual mounted components. On the other hand, there were discrepancies between the experimental values and the analytical values at locations between the structural parts of (a) and (d). Between (a) and (b), the thermal flux from the surface of the heater to the back surface of the printed-circuit board was large, and difference arising from the state of contact at the various locations appear to be substantial. Furthermore, between (b) and (c), there was an effect from the ribs on the LCD holder in the LCD module, formed as it was from an air gap, a glass panel, a polarizing plate, an LCD holder, and other components. Locations between (c) and (d) are between the surface of the glass panel in the liquid-crystal module and the surface of the front case, where differences in the thermal diffusion effect appeared secondarily.

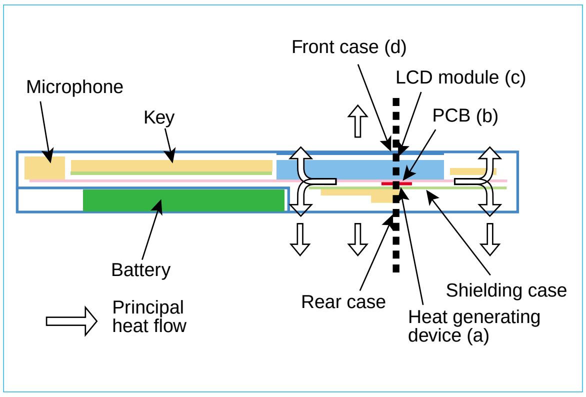

Fig. 4 Schematic cross-sectional diagram of a mobile phone

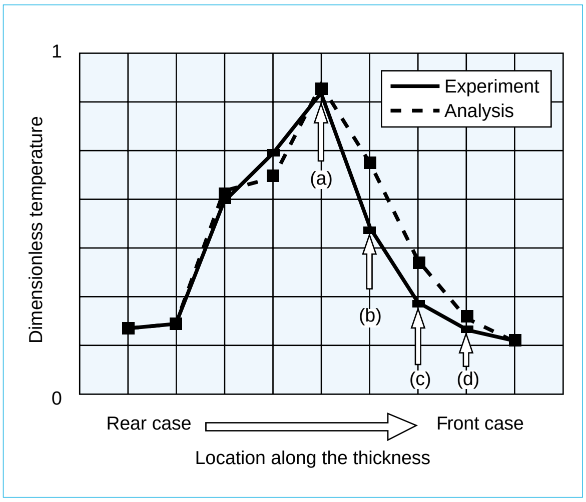

Fig. 5 Temperature distribution along the thickness of a mobile phone

Consequently, the temperature differentials between the internal components can be corrected through, for example, configuration analysis when packaging, and measurements of the material properties. The effectiveness of this analytical technique is clear.

The analytical model developed was applied to a W-CDMA mobile phone, and not only was it possible to select the component layout that showed the best distribution of heat generation at an early stage of the design but also heat-dissipation strategies using heat spreaders and high-thermal-conductivity rubber could be employed.

As mobile phones become more sophisticated, more aggressive development of mechanical design technologies will become necessary, in which the mounted components become larger and the external chassis becomes lighter and thinner, and in which designs with efficient thermal dissipation will be suitable for increasingly large amounts of generated heat. ❑

W-CDMA Mobile-Phone Imaging Technology

*by Yoshiko Hatano**

One of the features of W-CDMA mobile phones is their videophone functions, able to receive video content. In order to provide these functions, a camera signal-processing integrated circuit has been developed to transmit the captured images, along with a display controller for synthesizing the display of video images and graphics on both transmitter and receiver sides.

Fig. 1 shows the flow of signals in the imaging system. First the image captured by the camera module is input to the camera signal-processing IC and after image processing (such as zoom, special effects, etc.) the signal is MPEG-4 encoded. The encoder's data-stream output is multiplexed with the speech data, and sent on to the radio unit.

The raw image, prior to MPEG-4 encoding, is also output from the camera signal-processing IC and sent to the display controller. The display controller combines this pre-encoding raw image and the video-image output from the MPEG-4 decoder, overlaying any still image graphics generated by the CPU, and sends the results to the LCD. The various parts of the system are as described below.

Camera Signal-Processing IC

A block diagram for this unit is shown in Fig. 2. The input image is the QCIF size (176 pixels horizontal by 144 pixels vertical), with eight bits each for R, G, and B colors. Electronic zoom and special effects are performed on the captured image, and still-image graphics are overlaid. The still image graphics overlay is more than just this, generating a "hold" screen when, during the videophone session, the transmission of the locally generated image is paused.

The video encoder offers selection of MPEG-4 Simple Profile Level 0 and H.263. When using

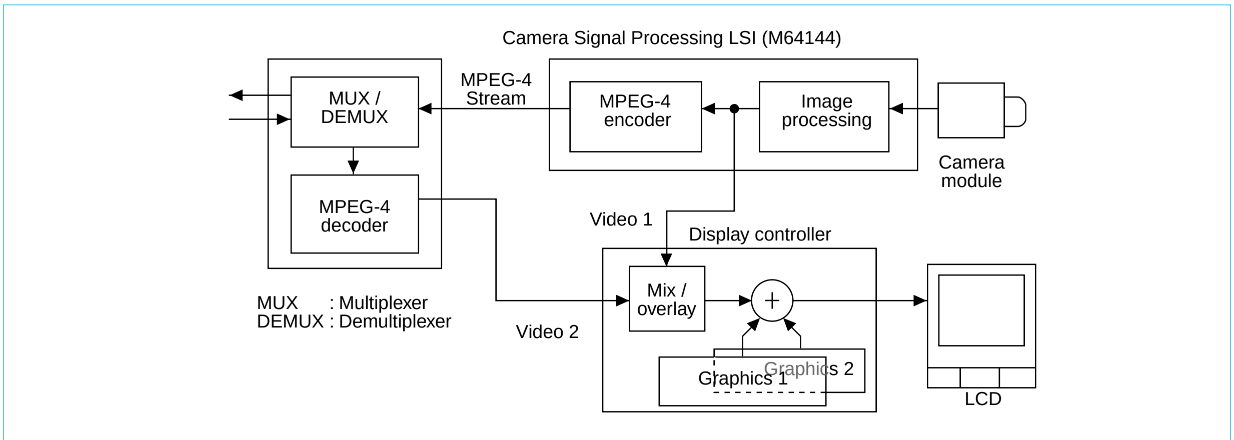

Fig. 1 Total block diagram for video-system processing

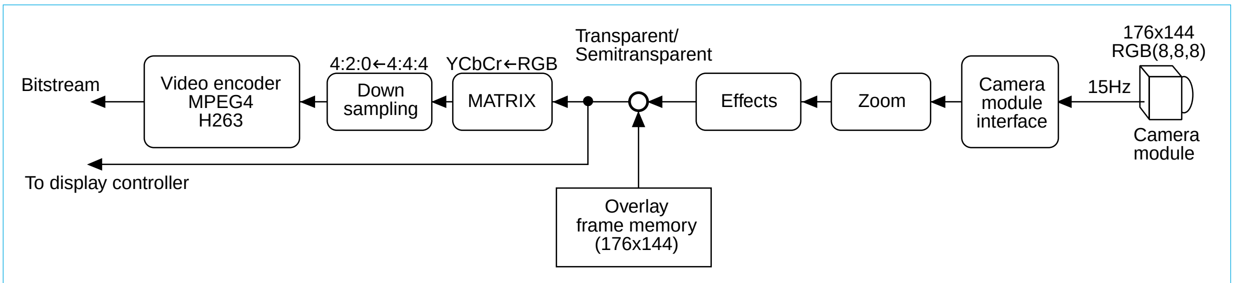

Fig. 2 Block diagram of camera signal processor LSI

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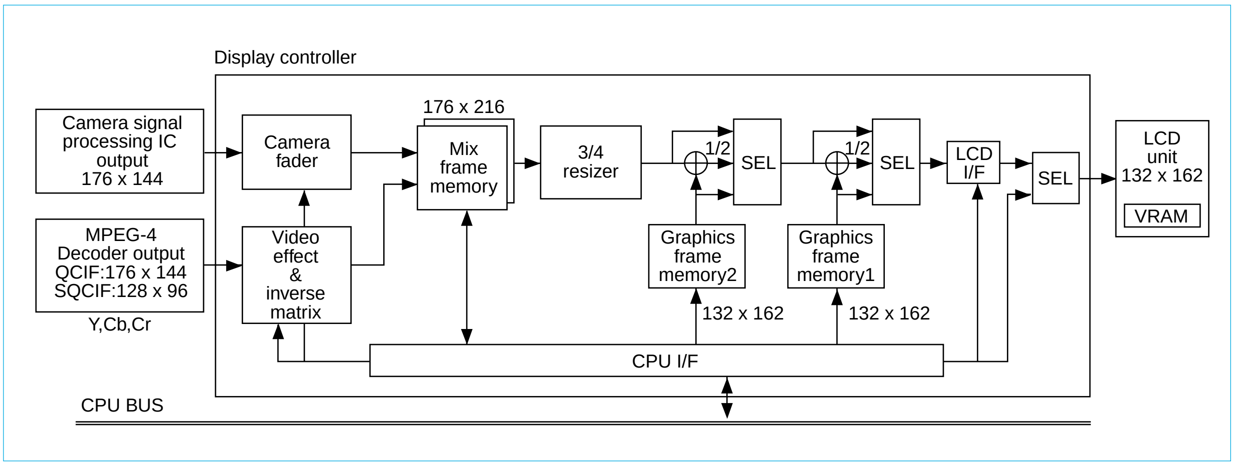

Fig. 3 Clock diagram of display controller

MPEG-4 encoding, data partitioning and reversible variable-length codes (RVLC) are used to achieve error resilience throughout the videophone session. Furthermore, to reduce delays during the videophone session, the system exerts control to ensure that no frame occupies more than 512 bytes of the buffer.

The most time-consuming process in the video encoder is motion estimation. The IC uses a motion-vector detection algorithm that determines a search area adaptively based on the surrounding motion vectors, thereby reducing the average calculation load to 27.2% of that in previous systems. Furthermore, a low power consumption of only 50mW has been achieved by optimizing the partitioning of tasks between hardware and firmware, and by the use of a gated clock. The features of this camera signal-processor IC are summarized in Table 1.

Display Controller

The display controller has a CPU interface, an MPEG-4 decoder interface, a camera-signal interface, and an LCD-module interface, and is able to synchronize graphics and video images, partition areas as desired, generate mixed images, and display the images on the LCD module. Fig. 2 shows display-controller features, while Fig. 3 shows the system configuration.

Because two video streams are input asynchronously, the display controller has two frame memories for video, where the timing is adjusted by switching between writing and reading.

The video and graphics synthesis is synchronized with the completion of the writing for each image, where the timing is adjusted to output to the LCD only the regions to be written, thereby reducing the power consumption.

The above article summarizes the imaging technology used in W-CDMA mobile phones. The video communications functions of these mobile phones seem sure to advance still further in the future. This will make it necessary to improve the performance of cameras, LCDs, and video-processing ICs, and to reduce their power consumption. Furthermore, the graphic functions in the mobile phones must be easy to operate, fun to use, and stable whatever the environment in which they are used. Mitsubishi Electric is therefore commited to ongoing research in imaging technologies for these types of application. ❏

Table 1 Features of the Camera Signal-Processor IC

Input video	QCIF (176 x 144 pixels), RGB (8 x 8 x 8 bits)
Electrical zoom	1.5X/2X
Image effects	Posterization, monotone, sepia, negative
Still picture overl	Overlaying image: 176 x 144 pixels, RGB (5 x 5 x 5bit) Transparent, semitransparent
MPEG-4 encoder	Simple Profile Level 0 Bit rate: 64kb/s (max) Frame rate: 15Hz (max) Data partitioning Reversible VLC
Power consumption	Approx. 50mW
Package	175-pin FBGA

Table 2 Features of the Display Controller

Input	Video 1: QCIF (176 x 144 pixels) Video 2: sub-QCIF (128 x 96 pixels) Graphics: 132 x 162 pixels
Output	132 x 162 pixels, 262,144 colors, LCD format
Functions	Level control, Mirror image, Rotation for Video 1, 2. Size conversion by 3/4 for Video 1, 2. Still image capture and still image display for video Picture in picture with Video 1, 2. Overlay graphics 1, 2 on Video 1, 2. Transparent, semitransparent.

W-CDMA Mobile-Phone Design

*by Yoshihito Nakahara and Tomoaki Tsukada**

A W-CDMA (Wideband-Code Division Multiple Access) service has been developed by NTT DoCoMo. The service provides high speed/high quality communications, prompting changes in the ways in which mobile terminals are used, and changes in the design of mobile phones. This article describes an image of the future offered by this W-CDMA service to its users, identifies new concepts, and addresses the issues of mobile-phone design and a new GUI for them. The key concepts in the new design are as follows:

Proposal: Double Screen

One proposed form of the mobile phone, using a double screen, is presented as a multimedia tool, conceived as able to handle more sophisticated services and capable of executing multiple applications simultaneously.

Proposal: Separable Terminals

An evolved form of mobile terminal is presented as a communications tool, demonstrating the feasibility of multitasking and the use of the mobile terminal while engaging in other activities.

As a result of the design work, prototype mockups were exhibited in Germany at both the 2001 and 2002 CeBIT, where they were seen not simply as studies in styling but as definite steps towards identifying specific advances and pointing the way to the next generation of mobile terminals.

Envisioning the Types of Use in the Future

Video contents, video mail, and videophone services are at the heart of multimedia services in W-CDMA today.

1. In the introductory phase, the technologies will develop more varied and sophisticated functions.
2. During the growth phase, as the degree of diversity of integrated services increases, we can expect to see increasingly large variations and changes in the terminal itself.
3. In the mature phase, as the terminal becomes ubiquitous, there will be advances in the

Fig. 1 The mobile-phone concept mockup displayed at CeBIT 2001

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direction of wearable and customizable terminals.

This article discusses the double-screen concept, envisioned for Stage 1, and the separable terminal concept envisioned for Stage 2.

Feasibility of the Double-Screen Design

The double-screen design is a prototype based on the concept of providing more sophisticated services.

BACKGROUND. There are calls to increase the screen area in the pursuit of more easily legible liquid-crystal displays that can display a larger amount of text in mobile phones. Note that the types of media handled by mobile phones are diversifying, as shown in Fig. 2.

Fig.2 The wearable concept mockup

One way of fulfilling the dual objectives of increasing screen area (in order to cope with the sophisticated functions that will result from the wider range of media handled) while maintaining the mobile phone's compact form factor is to link together two screens.

THE DOUBLE-SCREEN CONCEPT. This can be summarized as a multilayer compilation communications terminal. The concept is to make it possible for users to access sophisticated functions and services without having to go through complicated operations. This will contribute high added value in the form of linked media communications that will accompany increasingly sophisticated communications. These are the basic desires of mobile-phone users. The designers focused on an effective method of using a second layer screen, where the screens slide and are displayed only when operations require their use. Applications envisioned as using these second-layers screens include:

1. Checking or manipulating attached images when replying to mail.
2. Displaying information about stores, restaurants, etc., on the map while using navigation functions.
3. Displaying, at the same size, both the image of the user and the image of the person to whom the user is talking when using the videophone function.
4. Playing competitive games while watching the opponent's face.

GUIS FOR DOUBLE SCREENS. The interface structure is being studied based on the following three scenarios:

1. Mail functions and browser functions are linked together.
2. Videophone functions and other functions are linked together.
3. Navigation functions and local information search functions are linked together.

In these studies, the basic requirements are:

1. That the basic operations can be performed even on a single screen, and
2. That the interface shifts to the double-screen mode as and when necessary.

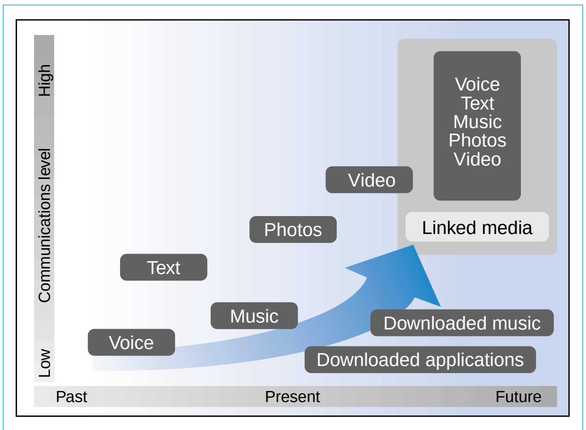

Fig. 3 Increasing media on mobile phones

Envisioning these basic requirements makes it possible to satisfy the needs of both basic users and those who take advantage of more sophisticated communications functions.

Given this, the guiding principle for the GUI is that of a "support display" that can clearly show the superiority of the shift to the double-screen mode. In this proposal, the two types of user support come down to specific examples of making it possible to multitask clearly distinct applications, making it easy to find other information required in the various operations, and making it possible to arrive at one's objective with a minimum of operations.

The double-screen concept also has the advantage of increasing the degree of freedom in design, maintaining portability and power-saving, in additional to its benefits for user interfaces. The double-screen approach seems sure to play a powerful role in differentiating such units from other mobile phones.

These results attracted a great deal of attention when exhibited at the information device exhibition in March of 2002 (CeBIT2002). Before the exhibition, studies had been performed to evaluate the degree to which the concept would be accepted by the market.

The design of future devices (phones and terminals) will depend critically on studies of the marketability of new devices and interface design will be difficult.

Developments in Separable Design

Separable design builds on a design concept envisioning multichannel services in the future, and has been validated in the creation of image videos depicting use scenarios.

BACKGROUND. When multichannel services are used in the future, it will be possible to operate the terminal equipment while multitasking–looking at the display while listening to the audio or while taking pictures. Because of this, the separable design approach has been proposed as a structure with even more flexibility than the double-screen design.

THE SEPARABLE DESIGN CONCEPT. This concept provides flexibility in the way the device is held by providing independent units, with a handset for phone conversations and a viewer for handling large volumes of data. The scenarios for use include phone or videophone conversations, while sharing image information, holding the viewer in one hand and the handset in the other. Stackable units and pendent-type units are also envisioned, with portability in mind.

EXAMPLES FEATURING SEPARABLE DESIGN. First type: Stackable units, see Fig. 4. Second type: A unit that can be split into two from a shape folded into two parts, where the handset part inserts into the viewer, see Fig. 5 and 6.

Fig. 4 Concept mockup demonstrated at CeBIT 2001

Fig. 5 Separate type mockups


Fig. 6 Alternative separate type mockup

Future Outlook

Although continuing proposals and research from the users' perspective will be needed in the future, ultimately it will be necessary to consider ways of identifying specific hardware and software proposals. For example, proposals have already been made for how to implement functions in the double-screen and separable hardware structures. Even for past products, whenever links have been made between distinctive operating devices and GUIs, those links have become the distinguishing product features.

Knowledge of both hardware and software technologies will be essential in creating marketable designs for information equipment such as mobile phones. It will also be important for hardware and GUI design to combine in making the product appeal to the users in a variety of ways. This presupposes proposals and research firmly rooted in human experience.

The article discussed two approaches to W-CDMA mobile-terminal design developed from future use scenarios. The double-screen design, is particular, is eminently feasible from the perspective of improvements to the operating interface, and the proposal has been subjected to thorough research, including that into the associated GUI. However, packaging constraints present a variety of technical issues to be resolved in marketing such a product. These include the issue of size and of wiring within moveable parts. Further development work will be performed in cooperation with the engineering design department. ❑