VOL. 84/SEP. 1998

MITSUBISHI ELECTRIC ADVANCE

Mobile Communications Edition

MITSUBISHI
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Mobile Communications Edition

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TECHNICAL REPORTS

SPECIAL REPORT

MITSUBISHI ELECTRIC OVERSEAS NETWORK

Our cover photographs show the GSM-type MT-30 digital mobile telephone. This light-weight (170g) and compact (135 x 48 x 26mm) unit provides up to two hours of continuous conversation and 120 hours in standby mode using standard batteries, performance that puts it in the top class worldwide.

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Four issues: ¥6,000
(postage and tax not included)
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Chiyoda-ku, Tokyo 101-0054, Japan

Mitsubishi Electric Advance is published quarterly (in March, June, September, and December) by Mitsubishi Electric Corporation.

Overview

The Present and Future Trends of Mobile Communications

*by Michio Nakanishi**

The systems responsible for mobile communications are increasingly adopting digital technologies, and expectations are rising for the move from voice communications to multimedia communications. Public systems promise to experience enormous demand, a trend supported by increases in living space and the diversification of economic activities. The eager acceptance given to the immediacy and simplicity of mobile communication has resulted in its adoption by users in many different age groups, and it is increasingly important for information communications. By the end of 1997, some 204 million subscribers in more than 100 countries were using mobile telephones.

In Japan, mobile telephones including the PHS system had attracted more than 37.6 million subscribers by February, 1998, rapidly approaching the high levels of penetration in the Scandinavian nations. Investigations of and research into mobile telephone systems are underway in many nations, seeking to identify those that will provide more effective means of coping with large numbers of subscribers than the current implementations of cellular phones using GSM, PDC, D-AMPS, etc., and mobile phones using CDMA, etc., already in use in the U.S.A. Among these is the next-generation IMT-2000 (FPLMTS) communications system, which is being prepared for implementation in the year 2000 in Japan, Europe and the U.S.A. Studies of this next-generation system are concentrating on unified national standards that will enable a single handset to function with universal compatibility while at the same time handling multimedia communications. Research is also under way into links between next-generation high-speed radio communications access systems and mobile satellite communications systems. On the other hand, mobile business communications in Japan are about to go over to digital technologies and to progress from voice to multimedia communications. ❑

Michio Nakanishi is a Director, Communication Systems Group.

The Development of Digital Mova D203 Hyper

*by Tetsuaki Oga and Shin'ichi Fukui**

Mitsubishi Electric's easy-to-use Model D203 digital cellular phone is an 800MHz PDC type that features a compact lightweight design, extended battery standby and operating time, and the ability to display text messages (using the Short Message Service) on a four line by ten character LCD panel with electroluminescent lighting for nighttime use.

In 1996, Japan had nearly 21 million digital cell phone users, and the market is continuing to grow. In June 1997, Mitsubishi Electric launched Model D203, developed under the guidance of NTT Mobile Communications Corporation for the company's 800MHz PDC digital phone service. The cell phone boasts several user-friendly features. Extensive measures to lower power dissipation have extended the battery operating time to 90 minutes of continuous speech and 200 hours on standby with a standard battery, or 190 minutes of speech and 420 hours on standby with an L-size battery. Incoming calls can be signaled by an audible ring tone or a silent vibrator, permitting discreet use, while the flip-open handset need not be open to answer calls, simplifying operation and enhancing reliability. Model D203 supports Japan's short mail service, available since June 1997, displaying messages on a four-line by ten-character screen. A bright electroluminescent backlight illuminates the screen for nighttime use. The product is available in cosmic blue and glossy gray finishes. Fig. 1 shows a photograph of the Model D203.

Fig. 1 Model D203 digital cellular telephone.

Specifications

Table 1 lists the specifications and Fig. 2 shows a circuit block diagram. The unit measures 123mm high, 40mm wide and 26mm thick and weighs 120g with a standard battery—lightweight and convenient for handheld operation. The L-size battery, which extends the operation and standby time, increases the width to 38mm and the weight to 155g. The flip-open case was designed to protect the keypad from impacts and accidental operation.

Table 1 Specifications

Battery type	S	L
Dimensions (LxWxD)	123 x 40 x 26mm	123 x 40 x 38mm
Weight	120g	155g
Battery type	Lithium ion	
Nominal operating voltage	3.6V	
Nominal capacity	600mAh	1,300mAh
Charging time	80min	190min
Transmit power	0.8W	
Frequency band	800MHz	
Talk time (max. power, full rate speech coding, "off" power saver mode)	90min	190min
Standby time	200h	420h

Transmitter Circuit

The I.Q. generator converts serial binary data

**Tetsuaki Oga and Shin'ichi Fukui are with the Mobile Communication Business Division.*

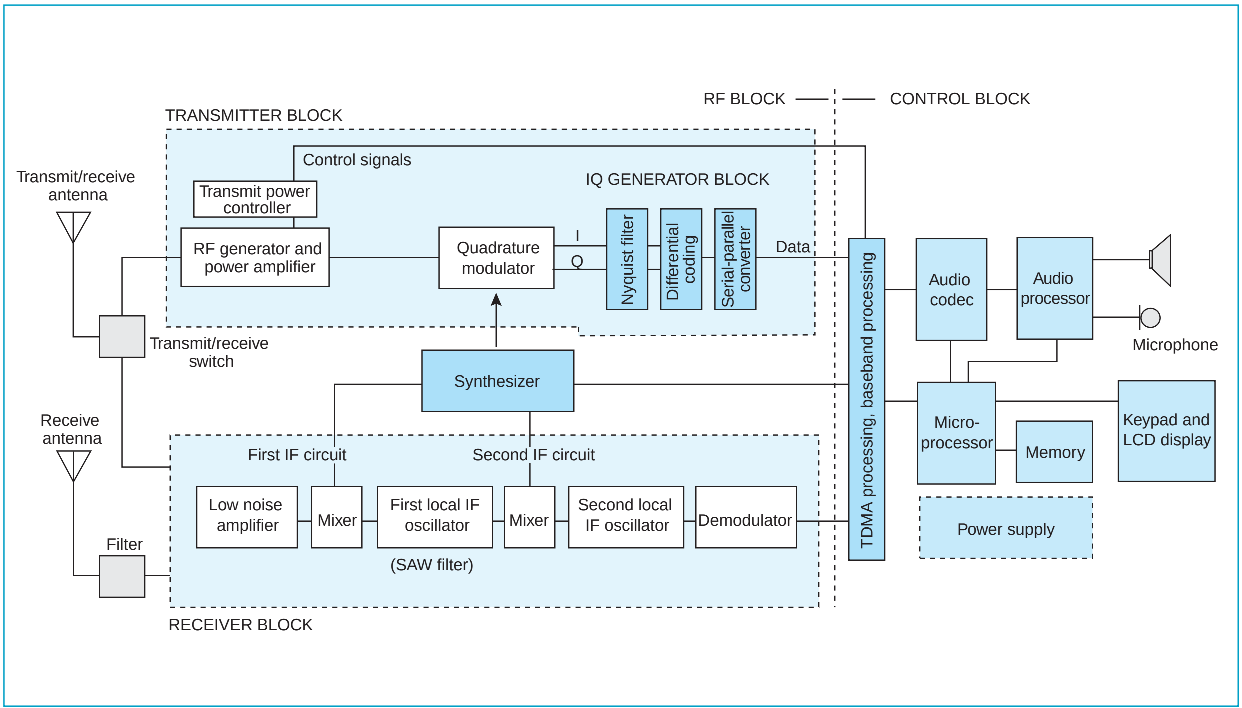

Fig. 2 Block diagram.

from a microprocessor in the logical control block to parallel data which is then differential coded and passed through a bandwidth-limiting Nyquist filter in preparation for $\pi/4$ quadrature phase shift keying (QPSK) modulation. The filter has a root Nyquist roll-off ratio of 0.5 that limits the width of the passband. The quadrature modulator performs direct quadrature modulation of the local transmission signal from the frequency synthesizer, which simplifies the circuitry and reduces the component count.

A compact two-stage GaAs amplifier has been used in the RF block, providing efficient, general-purpose amplification. Dual FETs are used to implement power control in six, 4dB steps.

Receiver Circuit

A diversity receiver coupled with a double superheterodyne amplifier is used to improve signal reception under conditions of poor wave propagation. A surface acoustic wave (SAW) resonator in the first IF filter saves space while a root Nyquist filter with a 0.5 roll-off in the second IF filter reduces distortion.

Frequency Synthesizer

A specially developed compact, power-saving ASIC, contains local oscillators for the transmitter and receiver circuits in both analog and digital bands. Produced using a BiCMOS process, the device includes mixers, amplifiers, switches and phase-locked loops.

Logical Control Block

This section controls the RF block, processes signals to and from the base station, performs connection management, decodes keyboard inputs, manages the LCD panel, serves as a speech codec, performs audio passband filtering and volume control, and manages the connection with a fax-modem adapter. The M30600 series microprocessor, a monolithic device with a 16-bit data path, is used as the processor. Flash memory holds the firmware. SRAM and EEPROM are also used.

Display

The LCD panel features a space-saving integrated driver circuit that is fabricated directly on the LCD glass cover using Mitsubishi?s chip-on-glass technology. The electroluminescent backlight is more than twice as bright as a point-source LED using the same power, and provides uniform illumination that makes the display easy to read in dark locations.

Careful engineering has resulted in a compact lightweight cell phone featuring extended battery operating time and support for text messages. The authors would like to express their thanks for the assistance of NTT Mobile Communications Corporation and the many individuals involved in the development project.❑

GSM and PCS1900 Digital Cellular Phones

*by Takayuki Nonami**

Since the GSM digital cellular phone standard was established in 1991, it has been adopted in about 100 nations and currently serves some 60 million subscribers. Mitsubishi Electric has recently developed a lightweight GSM cellular phone using 3V technology throughout to achieve a standby time in excess of 100 hours. This report introduces Model MT-30 for GSM applications and Model G100 for use under PCS1900, a GSM-based 1.9GHz-band system adopted by the United States.

The GSM Standard

The GSM system was developed by the Special Mobile Group of the European Telecommunication Standardization Institute (ETSI) based on ISDN network technology and time division multiplex access (TDMA) mobile communication technology. The basic functionality for the system was established in 1991 and Phase 1 trials were conducted in Germany in 1992. Mobile ISDN functions were implemented in Phase 2 trials beginning in 1996. ETSI is planning further additions and improvements to the GSM standard that will be tested in a Phase 2+ trial. Table 1 compares the functionality of each of these versions of the GSM standard.

Although GSM was originally developed as a common standard for 900MHz-band communications in Europe, it also serves as the basis for the 1,800MHz Digital Cellular System (DCS) and the 1,900MHz Personal Communication System (PCS) in the United States. Table 2 lists the specifications of these systems.

GSM features international roaming support, a short-message service that transmits text messages of up to 160 characters, call transfer and hold functions, conference calling services, 9.6kbps fax and data transmission, and a subscriber identity module—a card containing user information.

GSM Cellular Phones

Table 3 lists the specifications of Models MT-30 and G100. Model MT-30 features extremely compact dimensions of 35 × 48 × 26mm and weight of 170g while delivering state-of-the-art performance: two hours of active operation or 120 hours on standby with the standard battery pack. Model G100 was developed concurrently and has similar specifications. Table 4 lists accessories available for these two products.

Table 1 GSM Development History

	Phase 1	Phase 2	Phase 2+
Specifications development	1987~1991	1992~1995	1995~1999
Trial period	1992~1996	1996~1999	1998~2000
Voice transmission modes	Full rate	Full rate, half rate	Full rate, half rate, enhanced full rate
Data transmission	Full rate (9.6kbps max.), half rate (4.8kbps max.)	Full rate (9.6kbps max.), half rate (4.8kbps max.)	Full rate (11.4kbps max.), half rate (4.8kbps max.), packet transmission (76.8kbps max.), high-speed circuit exchange (78.8kbps max.)
Supplementary services	Call transfer, call limiting	Call transfer, call limiting, hold, caller ID, advice of charge, conference calls (6 parties max.), etc.	Enhanced versions of Phase 2 services
Short message service	Bidirectional text transmission, cell-specific announcements	Category-specific text transmission (basic, voice mail notification), cell-specific announcements	Phase 2 capabilities plus data packet transfer and two-byte code transfer
Other	Global roaming, 5V SIM card	Global roaming, 3~5V SIM card, DCS1800 specifications	Global and domestic roaming, SIM toolkit, multiband GSM/DCS support, interoperability with DECT

**Takayuki Nonami is with Mitsubishi Electric France.*

Table 2 Specifications of GSM and Derivative Systems

System	GSM	DCS1800	PCS1900
Transmit frequency	890~915MHz	1,710~1,785MHz	1,850~1,910MHz
Receive frequency	935~960MHz	1,805~1,880MHz	1,930~1,990MHz
Separation between transmit and receive channels	45MHz	95MHz	80MHz
Access method	TDMA-FDD		
Multiplex number	8		
TDMA frame length	4.615ms		
Channel spacing	200kHz		
Number of RF carrier channels	124	374	299
Modulation rate	270.833kbps		
Modulation type	GMSK, BT = 0.3		
Voice coding algorithm	22.8kbps RPE-LTP, 22.8kbps ACELP, 11.4kbps VSELP	22.8kbps RPE-LTP, 22.8kbps ACELP	22.8kbps RPE-LTP, 22.8kbps ACELP
User data transfer rate	2.4, 4.8 or 9.6kbps		
Waveform equalization	Up to 16µs		
Mobile unit transmission power	250mW avg., 2W peak	125mW avg., 1W peak	125mW avg., 1W peak

Key
TDMA-FDD Time division multiplex access, frequency division duplex
ACELP Algebraic code excited linear prediction
RPT-LTP Regular pulse excited, long-term prediction
VSELP Vector sum excited linear prediction

Table 3 Mobile Unit Specifications

Model	MT-30	G100
System	GSM	PCS1900
Dimensions	135 x 48 x 26mm with S battery	
Weight	170g (S battery)	
Supply voltage	3.6V	
Battery capacity	600mAh (S battery)	
Talk time	2 hours (S type, 50% DTX)	3 hours (S type, 50% DTX)
Standby time	120 hours (S type)	
Voice transmission	22.8kbps RPE-LTP	22.8kbps RPE-LTP, 22.8kbps ACELP
Data transfer rate	2.4, 4.8 or 9.6kbps	
Peak transmit power	2W	1W
Transmit frequency	890~915MHz	1,850~1,910MHz
Receive frequency	935~960MHz	1,930~1,960MHz

Table 4 Accessories

AC adapter	Available for US, UK, continental Europe and Australia
Battery pack	600mAh S type, 650mAh M type, 1,150mAh L type
High-speed desktop charger	Fits main unit and spare battery
Cigarette lighter charger	For rapid in-car charging
"Hands free" adapter	For hands-free operation while driving
Headset	*Quasi* hands-free conversation
Data adapter	PCMCIA card for fax and data transmission
Data cable	RS-232C for SMS, etc.

Externally, the cellular phones consist of a flip-open case with a large LCD panel and keypad. Table 5 lists the supported functions, which include a variety of call-transfer and supplementary services in addition to basic voice communication and speed-dialing functions.

Fig. 1 shows a block diagram of the MT-30/G100, which is divided into RF and baseband sections. Both sections operate on a single 3V power supply. The RF section consists of a power amplifier for the transmitter, a receiver amplifier and an RF processor for transmit and receive functions. The baseband section consists of a microprocessor, DSP and ASICs for baseband and audio processing. Fig. 2 shows the configuration of the system software, which is based on a realtime multitasking operating system.

Fig. 3 shows the configuration of the baseband processing ASIC developed for this application. The device has an analog section with a GMSK modulator and demodulator ADC, and a digital

Table 5 Mobile Unit Functions

Display	4 lines of 12 characters each, double height character support, 11 icons
Control panel	4 cursor keys, 4 function keys, 2 volume control keys, 12-key touch-tone keypad
Antenna	Fixed 25mm
Connectors	RF, DC input, headset, SIM, external I/O
Communication services	Voice communication, emergency calls, bidirectional text message transmission, voice-mail and other notifications, fax and data transmission
Supplementary services	Call transfer, call restrictions, hold, conference calls, caller ID, advice of charge, extension calls and transfers
Speed dialing	Fixed and programmable speed dialing memory, redial, storage of called party's phone number, storage of non-answering party's phone number, scratch pad memory
Other	Network selection, display language selection, keypad lock, call elapsed time display

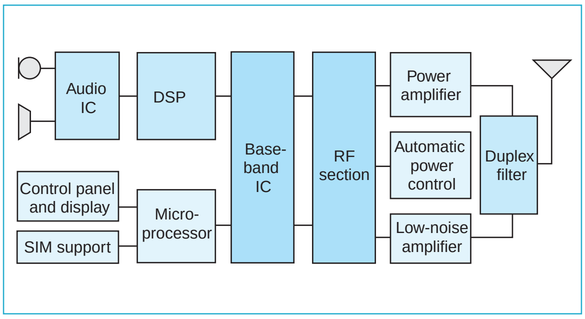

Fig. 1 Hardware configuration.

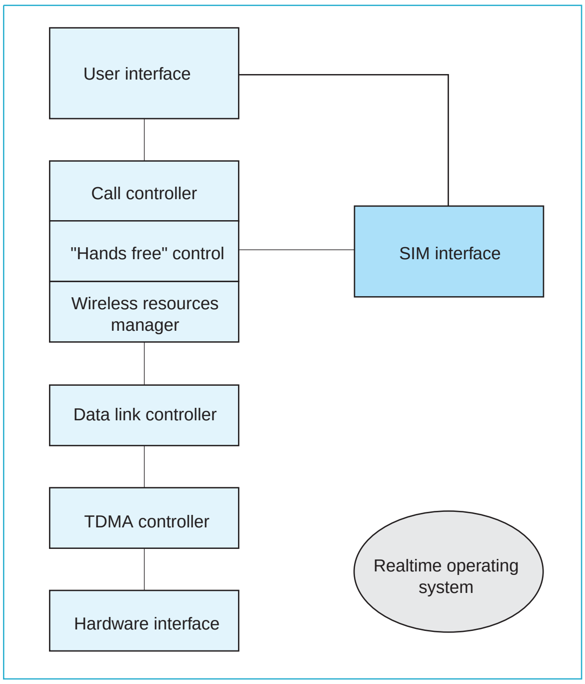

Fig. 2 Software configuration.

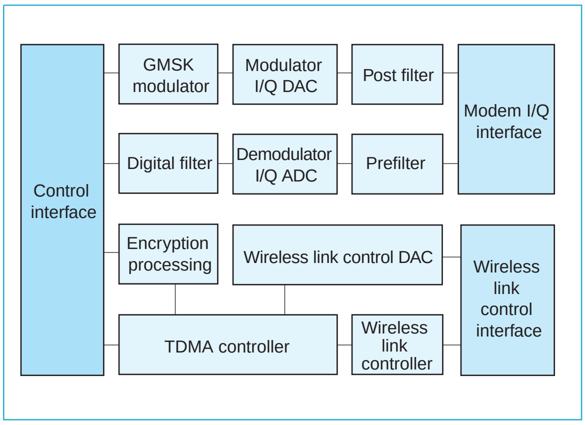

Fig. 3 Baseband IC configuration.

section with a TDMA controller and a microprocessor interface. The TDMA controller supports two clock frequencies, 13MHz and 32kHz, and switches to the slower frequency to save power whenever possible.

The DSP is a single-chip solution that implements a full-rate regular pulse excited long-term prediction (RPE-LTP) audio codec, an algebraic code exited linear prediction (ACELP) audio codec, error-correction coding functions for voice and data transmission and received signal sync detection.

The cellular phone's 3V 2W RF power amplifier IC was developed specifically for GSM applications. This hybrid GaAsFET device has a volume of just 0.4cc while achieving better than 50% efficiency.

Mitsubishi Electric plans to develop smaller and lighter GSM cellular phones based on the technologies presented here while tracking other industry trends and continuing to extend battery operating time. ❑

Development of Model MT151 *Mobile* Access™ Phone

*by Kiyoshi Takahashi and Akira Matsumoto**

The Model MT151 *Mobile* Access™ phone is a cellular telephone incorporating software and hardware that provides access to a variety of Internet services while maintaining the lightweight portability demanded of handheld mobile phones. This *Mobile* Access phone implements these capabilities using Cellular Digital Packet Data (CDPD) wireless packet data communications technology and Unwired Planet's UP.Link application technology.

Mitsubishi Electric's *Mobile* Access phone adds CDPD functions and the UP.browser to the standard cellular telephone functions of the United States' Advanced Mobile Phone Service (AMPS). The stand-alone unit can send and receive email and use various Internet services without connecting a personal computer. Because the applications and processing are performed on a web server, the system is highly flexible, allowing corporations to deliver custom user application services over private intranets. The UP.browser functions are tightly integrated with the cellular phone functions, allowing users to dial any telephone numbers appearing on a web page without using the keypad. To protect data privacy, CDPD and UP.Link incorporate encryption and authentication functions that operate transparently, without user intervention.

The photograph in Fig. 1 shows the *Mobile* Access phone. The unit features an LCD screen displaying four lines of 12 characters, a 24-key keypad with integral touch-tone pad, as well as antenna, microphone, speaker and battery pack. On the side of the unit is a serial connector for attaching a personal computer and on the bottom a connector for the cigarette lighter socket in a car or other accessories.

At the heart of the phone is a Mitsubishi 16-bit microprocessor, type M37702. Programs are stored in flash memory to allow updating. The processor runs a multitasking operating system with realtime control capabilities. Software execution is managed by a realtime monitor.

Fig. 1 Mitsubishi Electric's Mobile *Access phone.*

CDPD

CDPD is a wireless packet data communication system that utilizes open channels in AMPS, the U.S. analog cellular phone system. Because it employs unused channels, the system is easily implemented, requiring little, if any, additional investment in base-station equipment. Service areas have expanded dramatically since the first field trials were conducted in 1994. Some 12% expansion was recorded in the first six months of 1997, and as of May 1997, services were available to half of the U.S. population. CDPD uses the OSI reference model shown in Fig. 2. Internet connections are supported by using the IP protocol in the network layer and assigning each mobile telephone an IP address.

Layer 3	SNDCP	MNRP
Layer 2	MDLP	RRM
Layer 1	MAC	

Key
SNDCP Subnetwork Dependent Convergence Protocol
MNRP Mobile Network Registration Protocol
MDLP Mobile Data Link Protocol
MAC Medium Access Control
RRM Radio Resources Management

Fig. 2 OSI reference model.

**Kiyoshi Takahashi and Akira Matsumoto are with the Communication Systems Development Center.*

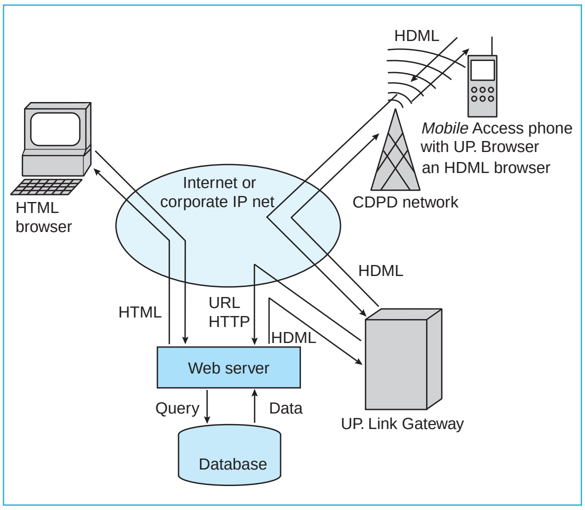

Fig. 3 Description of a Network using UP.Link.

The CDPD protocol also features a standby mode with intermittent operation that increases mobile phone standby time compared to the standard AMPS standby mode.

UP.Link

The *Mobile* Access phone uses the UP.Link communications software developed by Unwired Planet. This technology provides Internet access to cellular phones despite the limitations of the small display screen. Fig. 3 shows the configuration of a network connection implemented using UP.Link technology. UP.Link Gateway serves as an intermediary between the web server and UP.Browser, the *Mobile* Access phone's browser application, converting the web's HTTP protocol to a low-overhead proprietary protocol and keeping track of accounting information. The UP.Browser has a restricted feature set designed to operate on a cellular phone with limited memory capacity and modest processor performance. The browser used Handheld Device Markup Language (HDML) in preference to the HTML used in standard web pages and browsers.

The *Mobile* Access phone accesses the Internet via UP.Link Gateway. The server delivers information coded in HDML to the screen, whether stock prices or weather forecasts from the Internet, or inventory data from a database on a corporate LAN. The HDML information passes through UP.Link Gateway to the UP.Browser for display on the *Mobile* Access phone's screen. Although the screen displays only text information, we believe that the ability to readily access the Internet from a pocket-sized terminal will create a new market for handheld information equipment. Table 1 lists typical services that could be delivered by the Internet or a corporate intranet.

Table 1 Typical UP.Link Based Services

General-purpose	Electronic mail, personal information manager, news, stock prices, air travel itinerary
Business	Sales information, order status, inventory data, client data
Consumer	Banking services, personal news services, yellow pages, movie schedules, lottery results, astrology readings, games

The combination of cellular phone and Internet access capabilities in Mitsubishi Electric's *Mobile* Access phone offers to provide mobile travelers with email connectivity and other data services without a separate computer. ❑

Note: *"Unwired Planet," "UP.Link," "UP.Browser," "HDML" and "Handheld Device Markup Language" are trademarks of the Unwired Planet Corporation.*

A W-CDMA Modem for Mobile Next-Generation Communication Systems

*by Takahisa Aoyagi and Hideshi Murai**

Wideband Code Division Multiple Access (W-CDMA) offers effective frequency utilization and flexibility for variable data transmission rates, so that it is one of the most promising candidates among radio access technologies for International Mobile Telecommunications 2000. This article describes a prototype W-CDMA modem and reports on its field trials.

Trends in IMT-2000

Cellular telephone systems have been changing from first-generation analog types to second-generation digital types. Third-generation systems being planned for introduction in the year 2000 should increase capacity over that of the second-generation, and will support various data rates, including high data rates for images.

The International Telecommunications Union (ITU) is responsible for making the standards for third-generation mobile communication systems, or IMT-2000. In Japan, the FPLMTS research committee led by the Ministry of Posts and Telecommunications and the Association of Radio Industries and Businesses (ARIB) has engaged in IMT-2000-related technical studies since 1994, and at the end of 1996 decided to adopt W-CDMA in order to propose an IMT-2000 system using this technology to the ITU. In 1998, the European Telecommunications Standards Institute (ETSI) considers the field of candidate technologies to be W-CDMA and TD-CDMA. In the United States, CDMA 2000 (an enhanced N-CDMA known as IS-95) and wideband TDMA (enhanced Personal Communication Systems) are being considered.

Mitsubishi Electric has been actively developing W-CDMA technologies, especially coherent detection techniques, variable bit-rate transmission methods, and transmit power control technology. The company has also been working through ARIB on Japanese standardization activities and has made W-CDMA-related proposals to ETSI. This article introduces an adaptive variable bit-rate transmission system, and reports on indoor field testing of prototype W-CDMA equipment.

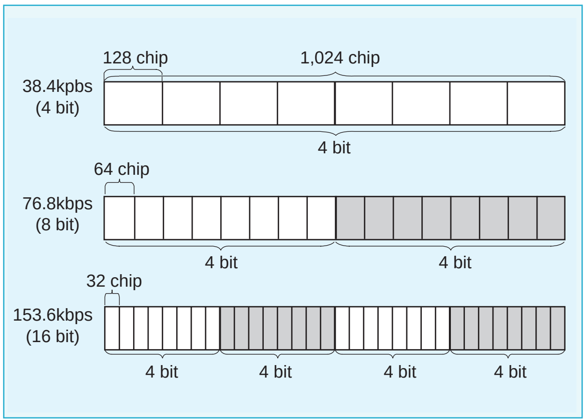

Fig. 1 Variable rate transmission method. Data rates of 307.2kbps and higher are achieved by multiplexing several of the signals shown.

Variable Bit-Rate Transmission

We studied an adaptive data rate scheme under which a W-CDMA modem adjusts its data transmission rate to suit varying requirements for voice, images or other data stream. Fig. 1 illustrates the variable bit-rate system.

USING BI-ORTHOGONAL SIGNALS FOR MODULATION. Use of this signal format improves transmission characteristics, decreasing the required E_b/N_o by about 2.2dB compared to BPSK using four-bit bi-orthogonal code without FEC under a bit-error rate of 10^{-5} in static channel. Fig. 2 shows the configuration of the modulator. In this system, the orthogonal code is selected on the basis of the information rate being transmitted. Transmission data B1, B2 and B3 lead to selection of an orthogonal Walsh signal of which the sequence length is 8. The sign of the signal is determined by B0. The demodulator detects the orthogonal code type and sign and demodulates the transmission data.

PROCESSING GAIN MODIFIED FOR TRANSMISSION RATE ≤ 153.6kbps. The chip number used to spread the encoded data is set at 32, 64 or 128 to suit the data transmission rate.

ORTHOGONAL CODE MULTIPLEXING FOR R > 153.6kbps. As shown in Fig. 1, when the trans-

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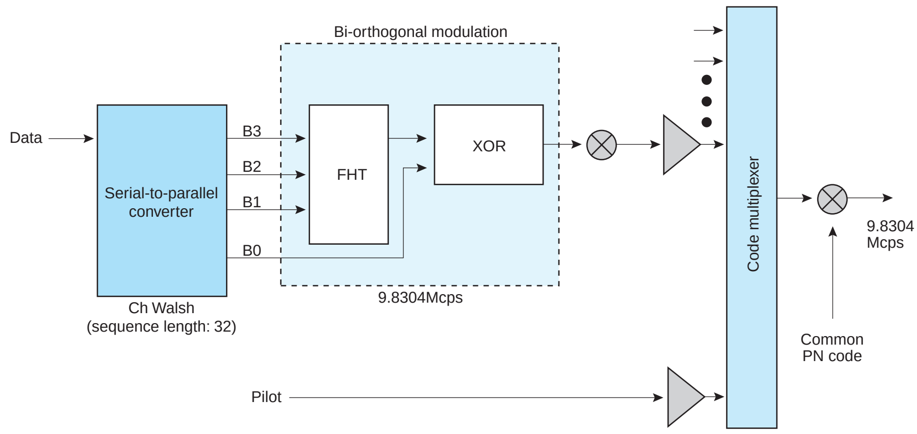

Fig. 2 Block diagram of modulator.

mission rate is 153.6kbps, the bi-orthogonal encoded bits are spread by 32-chip PN encoding, so that as shown in Fig. 2, orthogonal Walsh signals with a sequence length of 32 are multiplied by a bi-orthogonal signal, permitting multiplex transmission. Since code multiplexing is performed by orthogonal codes, cross-correlation between multiplexed signals is virtually absent, and transmission speed can be raised to the appropriate level for the number of multiplexed signals.

Since the processing gain in the multiplex encoding process is higher than the fixed defined value, the cross-correlation of the signal with transmissions from other W-CDMA stations is small, which has the effect of distributing and reducing interference effects among signals from nearby transmitters. Since the bi-orthogonal signal is a binary sequence with multiple information bits, fewer multiplex signals may be used than in multiplexing of BPSK signals, reducing the envelope variations.

Field Testing

We implemented a coherent detection RAKE receiver using the pilot channel as the phase reference and performed field tests in an indoor environment to determine multipath fading characteristics and open-loop transmission power control characteristics. Table 1 lists specifications of the test station. Fig. 3 show the delay profile. The maximum delay is 0.35~0.4µs, so that in this indoor signal propagation environment, the RAKE reception observation window of 0.4µs is a sufficient condition.

Fig. 4 shows the open-loop transmission power control characteristics. The control is effective in holding the received signal level

Table 1 Experimental modem specification

Transmission frequencies	
Downlink:	2,150.5MHz
Uplink:	1,990.5MHz
Power (at antenna)	0.1W
No. of channels	1 pilot channel, 0~2 data channels
Multiplexing system	Orthogonal code multiplexing
Data modulation method	BPSK/Bi-orthogonal transmission (k = 4)
Spreading method	BPSK
Transmission rate	9.6 x n kbps, for 1 ≤ n ≤ 32
Chip rate	9.8304MHz
Processing gain	15~30dB

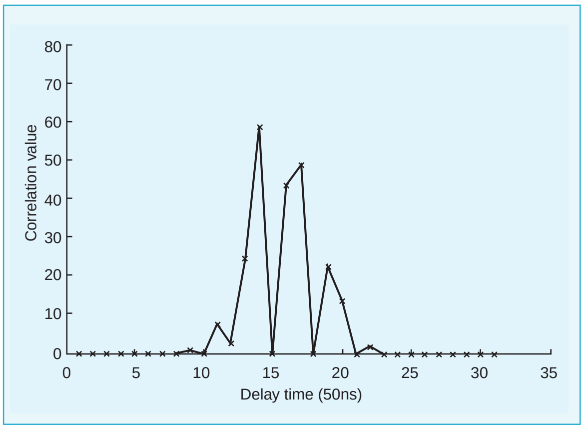

Fig. 3 Delay profile. Data points are at 50ns increments.

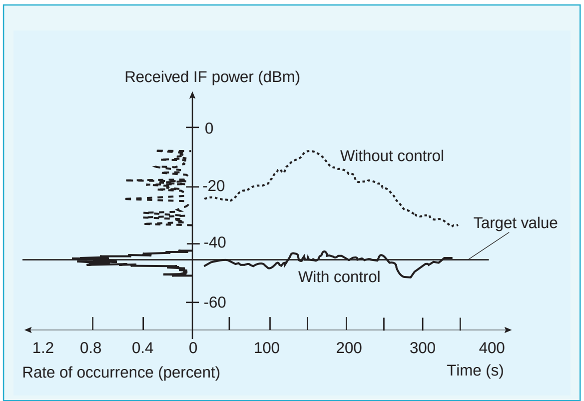

Fig. 4 Performance of open-loop transmission power control.

fixed relative to the central level. However, even if the 10MHz W-CDMA signal is used, there is a 10dB fluctuation, so that closed-loop control will also be required.

The technologies and test results presented here use different signal formats and specifications from Japan's proposals for IMT-2000; however, the transmission power control processing, detection technologies, and variable-bit-rate control technologies provide valuable experience and knowhow for future IMT-2000 systems. Having established basic W-CDMA technologies, Mitsubishi Electric will be shifting its focus to compact, low-power designs suitable for commercial products. ❑

Viterbi Equalization Technologies for Mobile Broadband Systems

*by Hiroshi Kubo and Keishi Murakami**

This article reports on a list-output Viberbi equalizer developed at Mitsubishi Electric for implementing multimedia applications in a mobile environment. The authors propose an algorithm for selecting and combining metric criteria based on estimated channel characteristics and developed an algorithm for high-speed compare-select operation.

Multimedia data transmissions in a mobile communication environment require high quality at a high data rate. However, increasing the data transmission rate leads to serious performance degradation due to increased vulnerability to fading effects caused by reflections and waveform distortion effects caused by variations in signal propagation speed along the transmission path. Specifically, at data rates above 10Mbps, delay effects can span from ten to several tens of bits. Viterbi equalizers and other adaptive equalizers can be effective under these conditions; however, correcting dispersion effects at higher data rates requires additional hardware complexity with reduced processing delay at the same time.

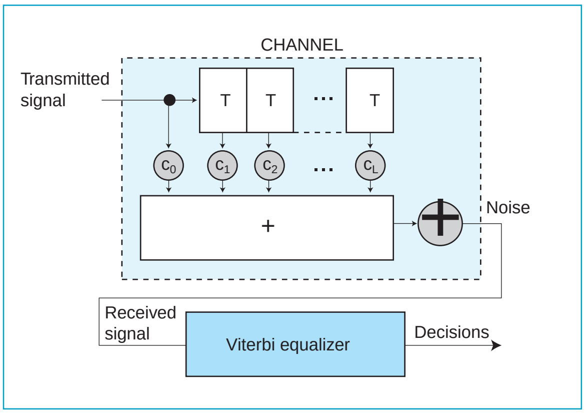

Fig. 1 Communication system model.

Communication System Model

Fig. 1 shows the communication system model. The channel is assumed to be a transversal filter. The channel tap coefficient for memory length L in the Viterbi equalizer is estimated, and the difference between the received signal and the replica signal based on this model is compared and the sequence that minimizes the error power is given as the decision sequence. In the optimum structure, the Viterbi equalizer provides maximum likelihood sequence estimation (MLSE)[1]. The error value is referred to a "metric." A squared metric is normally used, although a modified square has also been proposed.[2]

List-Output Viterbi Algorithm

The complexity of the MLSE grows exponentially with the channel memory length. The problem is solved by the list-output Viterbi equalizer.[3] The generalization of this device is as follows. The trellis memory length V is shorter than the transmission line memory length L, refering to the survivor path for its branch metric generation. For each state, several survivor paths are retained. Decision feedback sequence estimation (DFSE)[4] uses the first generalization. Complexity increases when the number of survivor paths S is large because of the sorting required for a list-output Viterbi equalizer.

Simulation Model

For the fading simulation model, we assumed that channel coefficients have equal averages, with a Rayleigh distribution, and an L value of eight. Modulation is BPSK and burst length is 200 bits.

A Simplified List-Output Viterbi Equalizer

Fig. 2 shows the configuration of a compare-select operation for a list-output Viterbi equalizer[5] that has been simplified as follows: some degree of selection errors are permitted, and if the upper level S path can be selected, the list need not be sorted into path metric order. The compare-select operations of a simplified list-output Viterbi equalizer with S = 8 has approximately the same delay as MLSE.

Fig. 3 shows the bit-error rate (BER) performance of a simplified list-output Viterbi equalizer. The "sorting" type shown is a conventional list-output Viterbi equalizer, the "fast" type is a simplified list-output Viterbi equalizer. The

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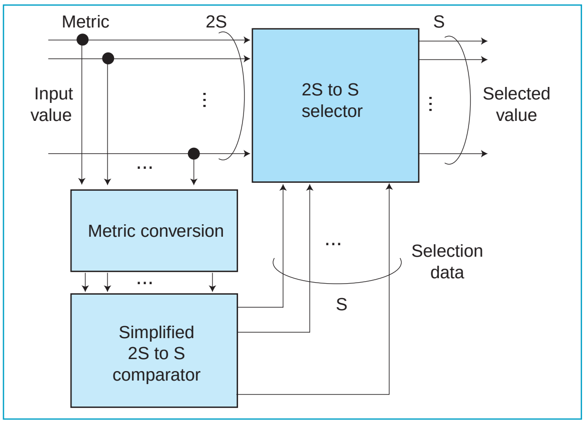

Fig. 2 Compare-select processor for a simplified list-output Viterbi equalizer.

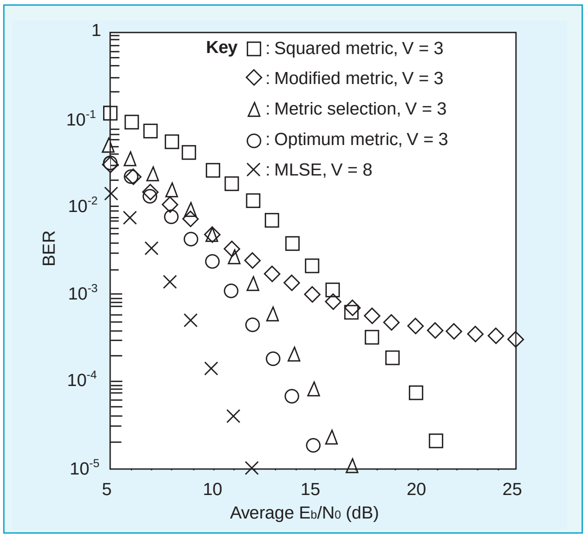

Fig. 4 BER performance of a Viterbi equalizer with metric selection.

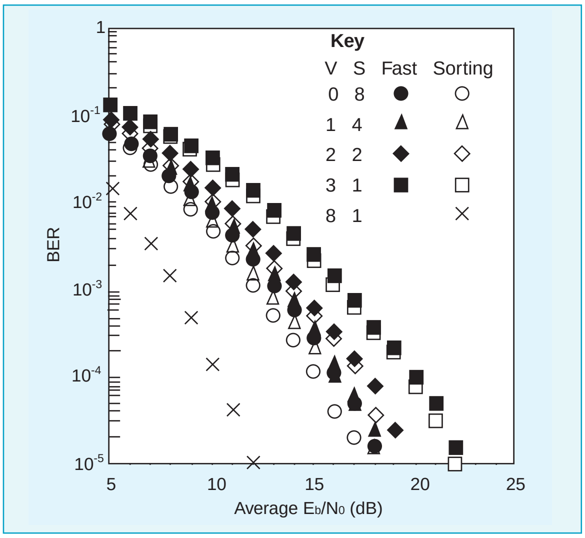

Fig. 3 BER performance of a simplified list-output Viterbi equalizer.

number of survivor paths for the overall algorithm has been set at eight. The figure indicates that the increase in the number of survivor paths S in each state improves the BER performance, so that performance degradation of the simplified processing is minimal.

A Metric Selection Viterbi Equalizer

Squared metric and modified metric criteria have different characteristics for list-output Viterbi equalizers. It is possible to improve the performance of a Viterbi equalizer by estimating the channel quality by a training sequence in each slot and then choosing the metric criterion with the better match or some weighted combination of the two.[6]

Fig. 4 shows the BER of a Viterbi equalizer using metric criteria selection, with trellis memory length V = 3. The proposed combination method yields better BER characteristics than either of the individual metrics over regions with a good S/N ratio, and performance close to that of the ideal metric is obtained.

With society's increased dependence on network connectivity, it is natural that these abilities be extended to mobile users of information equipment. Broadband mobile communication systems technologies, such as the Viterbi equalizer described here, help to make a wider data channel available for communications by processing the signal to suit the varying characteristics of the wireless transmission link between mobile user and base station. ❑

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An Improved Differential Detection Scheme Based on Maximum Likelihood Sequence Estimation

*by Toshiharu Kojima and Makoto Miyake**

Although differential detection is a suitable demodulation scheme for mobile communications, its bit error rate (BER) performance in an additive white Gaussian noise (AWGN) channel is inferior to that of a coherent detection scheme. To remedy this deficiency, Mitsubishi Electric has developed an improved differential detection scheme using maximum likelihood sequence estimation based on the Viterbi algorithm. The resultant scheme achieves good BER performance not only in AWGN channels but also in fast Rician fading channels and slow Rayleigh fading channels.

The improved differential scheme developed[1] by Mitsubishi Electric is a multiple differential detection scheme that improves the BER performance by estimating demodulation data from 1, ..., $N_{(22)}$ differential detection signals.[2,3] The method involves differential detection of phase changes in the specified symbol interval of the received signal. We call the developed scheme a "multiple differential phase detection" (MDPD) scheme, since its algorithm only requires phase information of the received signal.

Communication System Model

Fig. 1 shows the communication system model. In the modulator, an M-valued transmitted symbol a_i is Gray mapped to a transmitted phase differential phase $\Delta\theta_i \in \boldsymbol{S}$, where the set of transmitted differential phases $\boldsymbol{S} = \{2m\pi/M;$ with $m = 0, 1, \ldots M\text{-}1\}$.

Then, the transmitted signal phase θ_i is generated by differential encoding:

$$\theta_i = \theta_{i-1} + \Delta\theta_i \quad \text{(Eq. 1)}$$

and the transmitted signal $s_i = \sqrt{E_s}\exp(-j\theta i)$ of the differential MPSK signal is transmitted, where $E_s = E_b \log_2 M$, and E_b is the signal energy per bit.

In the channel path, AWGN n_i with the single-side noise power density N_o is added to the transmitted signal $\boldsymbol{s_i}$, resulting in the received signal $\boldsymbol{r_i}$. The demodulator estimates the transmitted differential phase sequence $\{\Delta\theta_i\}$ from the received signal sequence $\{\boldsymbol{r_i}\}$ and produces the demodulated symbol sequence $\{\hat{a}_i\}$.

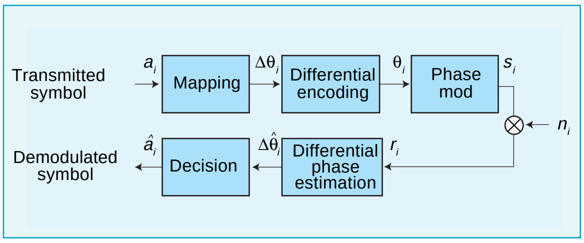

Fig. 1 Communication system model.

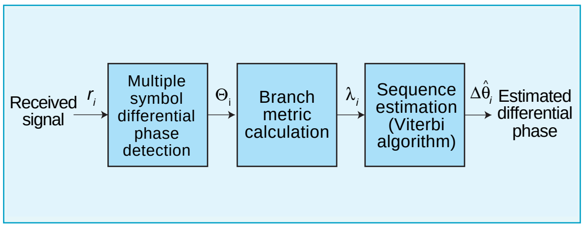

Fig. 2 Configuration of multiple differential phase detection scheme.

Configuration of the Multiple Differential Phase Detection Scheme

Fig. 2 shows the MDPD scheme configuration. In this scheme, 1, ..., $N_{(22)}$ symbol differential signals $\theta_{(1)i}, \ldots \theta_{(N)i}$ are generated from the received signal $\boldsymbol{r_i}$ by multiple symbol differential phase detection. When $\boldsymbol{r_i}$ is represented by $R_i \exp(-j\theta_{(0)i})$, $\theta_{(n)i}$ is represented by $\theta_{(0)i} - \theta_{(0)i-n}$.

Because of the differential encoding of Eq. 1, the N-symbol differential detection signal $\theta_{(N)i}$ contains information on a partial sequence of length N of the transmitted differential phase sequence $\{\Delta\theta_i\}$. By using this property, the MDPD scheme estimates the transmitted differential phase sequence $\{\Delta\theta_i\}$ from the differential phase symbol $\Theta_i = (\theta_{(1)i}, \ldots \theta_{(N)i})$ composed of the 1, ..., N-symbol differential detection signals.

The sequence estimation is performed by Viterbi algorithm with the trellis diagram having M^{N-1} states composed of N-1 elements of the set $\boldsymbol{S}$ of the transmitted differential phases.

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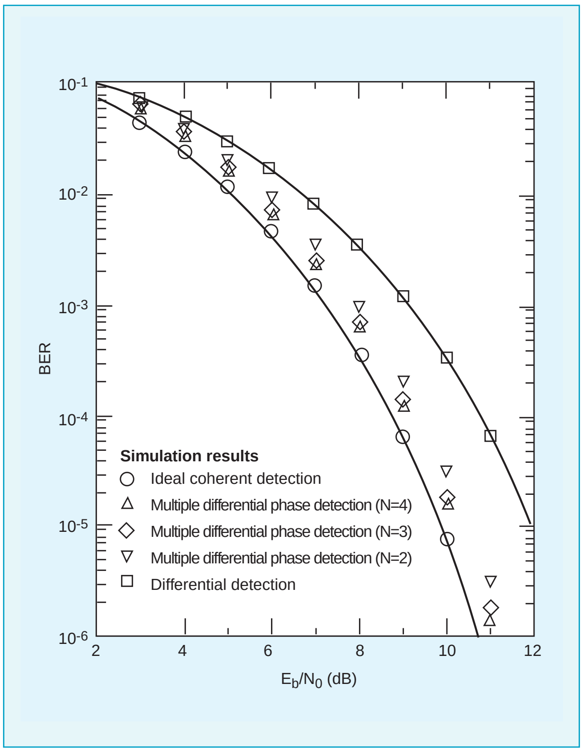

Fig. 3 Simulated BER performance in AWGN channel using differential QPSK modulation. Solid lines indicate theoretical values.

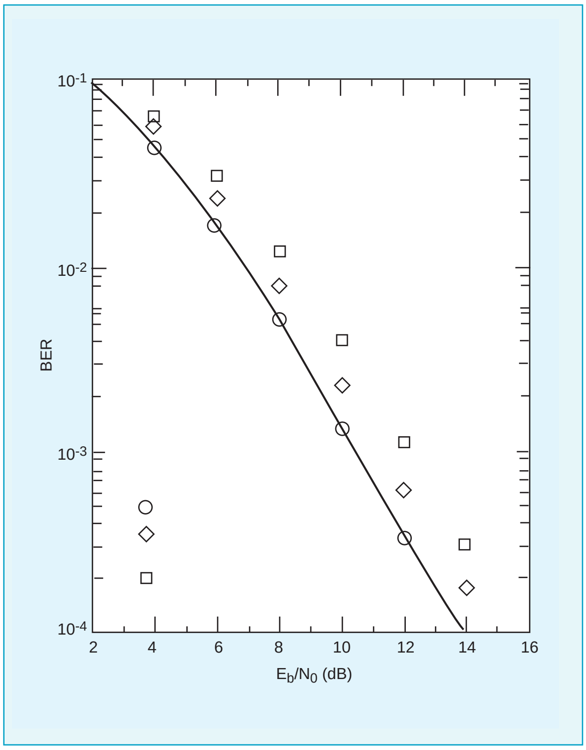

Fig. 4 Simulated BER performance in fast Rician fading channel using differential QPSK modulation with C/M = 10dB and $f_D T_s = 5 \times 10^{-2}$. Solid lines indicate theoretical values.

Consider the state transition on the trellis diagram from the state where $\Phi_{i-1} = (\phi_{i-N+1}, \phi_{i-N+2}, \ldots \phi_{i-1})$ at time $(i-1)$ to a state $\Phi_i = (\phi_{i-N-2}, \ldots \phi_{i-1}, \phi_i)$, at time i where $\phi_i \in \mathbf{S}$. The branch metric $\lambda(\Phi_{i-1}, \Phi_i)$ corresponding to this transition is given by

$$\lambda(\Phi_{i-1}, \Phi_i) = \sum_{n=1}^{N} \left| \theta_{(n)i} - \sum_{k=0}^{n-1} \phi_{i-k} \right| \quad \text{(Eq. 2)}$$

The differential detection signal $\theta_{(1)i}, \ldots \theta_{(N)i}$ for 1 to N symbols includes the independent noise $n_{i-1}, \ldots n_{i-N}$, so that the branch metric generation process has the effect of averaging the noise. As a result, the branch metric has a higher signal-to-noise power ratio than the original differential detection signal. Therefore, the BER performance of the MDPD scheme represents an improvement.

BER Performance

We will now describe the BER characteristics of a differential QPSK modulated signal processed using multiple differential phase detection, as measured by computer simulation.

BER PERFORMANCE IN AWGN CHANNEL. Fig. 3 shows the BER performance in AWGN channel. The MDPD scheme clearly improves the BER performance of the differential detection. The improvement in gain of BER performance increases with the total number of differential detection signals N. When $N = 4$, BER performance of the MDPD scheme close to that of coherent detection, i.e., within 0.3dB.

BER PERFORMANCE IN FADING CHANNEL. Fig. 4 shows BER performance in fast Rician fading

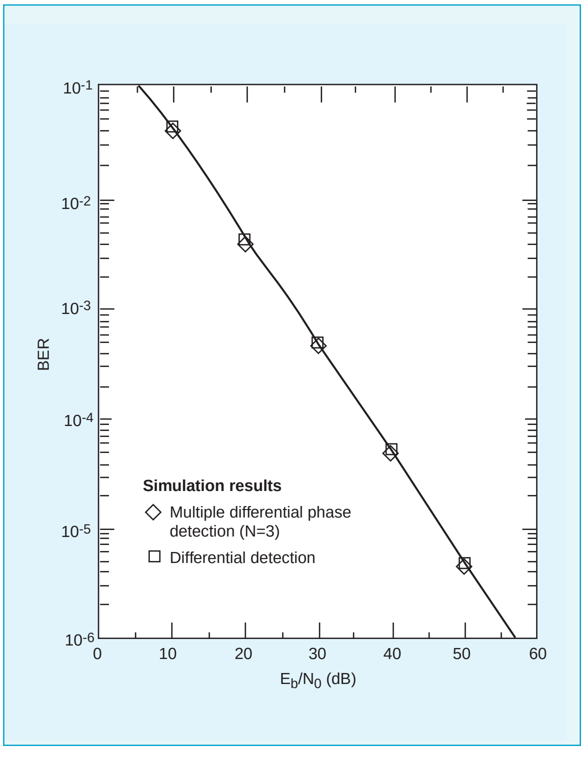

Fig. 5 Simulated BER performance in slow Rayleigh fading channel, using differential QPSK modulation with $f_D T_s$ = 1 x 10^{-4}. Solid lines indicate theoretical values.

with *C/M* (the Rice factor) = 10dB. In this case, the maximum Doppler frequency normalized by symbol duration $f_D T_s$ is set to 5×10^{-2}. It is evident from Fig. 4 that the MDPD scheme improves the BER performance of differential detection by at least 1dB. It is also evident that BER performance in this case is close to that of ideal coherent detection, despite the difficulty of a fast fading channel.

Fig. 5 shows BER performance in slow Rayleigh fading with $f_D T_s = 1 \times 10^{-4}$. The BER performance of the MDPD scheme is better than that of differential detection by 0.7dB.

The improvement in BER performance achieved by Mitsubishi Electric's successful development of a multiple differential phase detection system promises to improve the quality of digital communications not only in additive white Gaussian noise channels but also in channels affected by both fast and slow fading. ❑

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Low Bit-Rate Speed Coding Technology

*by Hirohisa Tasaki and Shin'ya Takahashi**

Speech coding technologies for compressing digital speech signals are being explored to help better utilize limited bandwidth resources and to support communications privacy. This article reports on recent developments at Mitsubishi Electric on low bit-rate speech coding technology which is central to cellular telephones and has numerous other applications.

Speech coding technology provides the voice bandwidth compression used in cellular telephone systems worldwide. The compressed signal has a bit rate of 3.45~13kbps, which increases to 5.6~22.8kbps when error correction is added. Most of these methods employ some type of the code excited linear prediction (CELP) algorithm illustrated in Fig. 1. This algorithm involves dividing the speech signal into 20~40ms frames, and then representing each frame by the best approximation of sound vectors from an excitation codebook. Only the indices of these vectors are actually transmitted. Although codebooks can be designed to capture the characteristics of speech, extensive calculations are needed to search for the best mix of vectors to express speech at low bit rates. Studies on codebooks and search methodologies are being conducted to reduce the computational requirements and increase the sound quality, while other studies are being conducted on increasing system robustness toward channel errors and background noise.

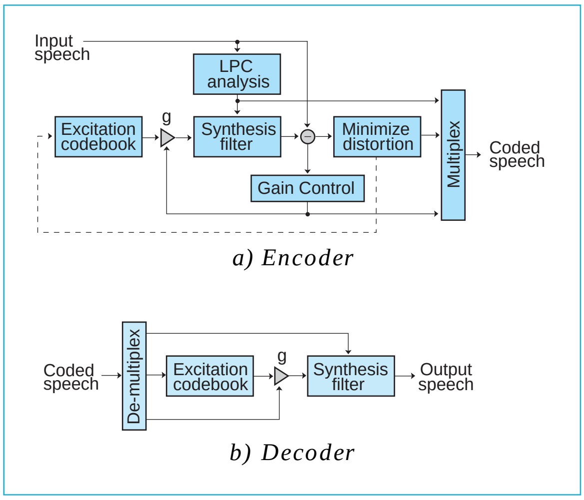

Fig. 1 Block diagram of CELP speech coder.

Table 1 Bit Allocation (bits/20ms)

Parameter	Mode	
	Basic	Transient
LSP	18	18
Power	6	6
Mode flag	1 x 2	1 x 2
ACB/FCB	8 x 2	—
SCB	(6 + 6) x 2	—
Algebra position	—	(4 + 4 + 4 + 5) x 2
Algebra sign	(1 + 1) x 2	(1 + 1 + 1 + 1) x 2
Gain	5 x 2	6 x 2
Total	80	80

Pitch-Position Synchronized CELP

Mitsubishi Electric has investigated pitch-position synchronized (PPS) CELP, in which the efficiency of the excitation signal representation is improved by use of an adaptive scheme based on the pitch peak position estimated by using prior samples. Fig. 2 shows the configuration of the PPS-CELP excitation signal generation system and Table 1 the bit allocation. The coding unit divides each frame into two subframes, encodes basic and transient modes for each, and selects the mode with lower distortion.

In the basic mode, excitation vectors are selected as a sum of vectors selected from a static codebook with fixed components and an adaptive codebook containing prior excitation components. Pitch-position selection involves choosing stochastic excitation vectors based on adaptive speech coding values. The head of the pulse train is positioned to minimize the distance between the synthetic signals created by adaptive excitation and the pulse train with the same interval as adaptive excitation. Called the pitch position point, this position is used as the center for stochastic excitation vector. A recent improvement has been to replace part of the

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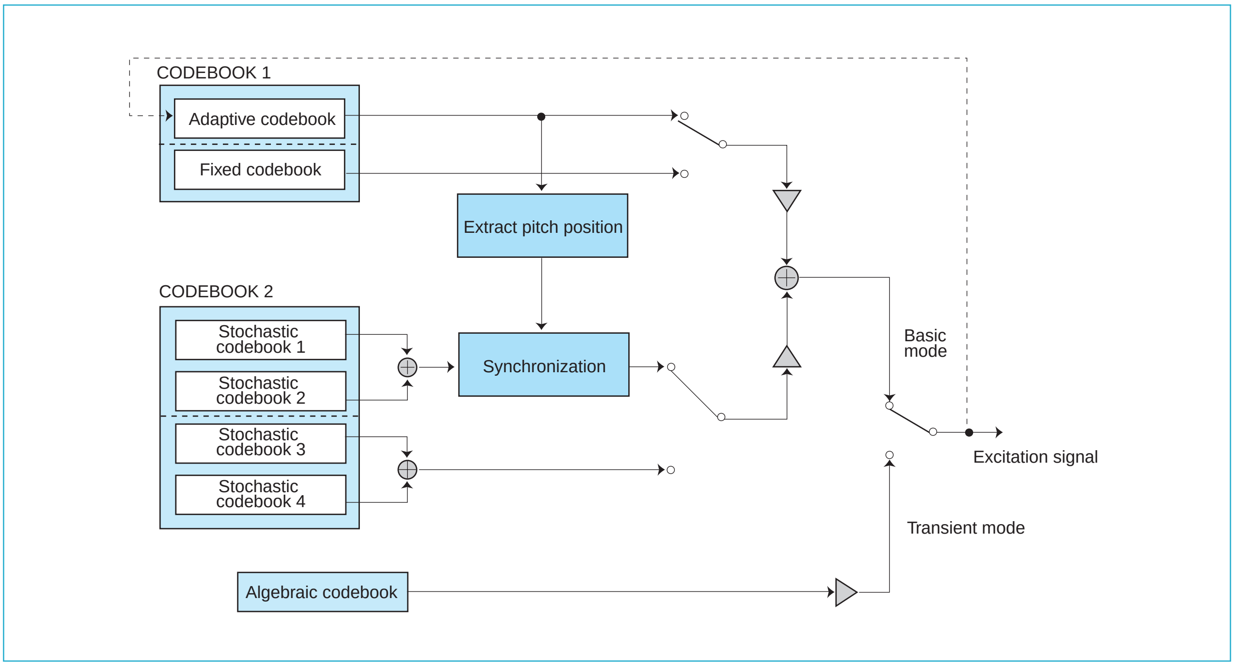

Fig. 2 Excitation signal generation of PPS CELP.

stochastic excitation codebook with pulse excitation.

In the transient mode, algebraic excitation is employed, with only pulse position and polarity used to encode the excitation signals. The basic mode has good coding characteristics under ordinary conditions where the pitch periodicity is high. Severe distortion occurs when major changes in sound level occur, leading to introduction of the transient mode, in which the optimum amplitude for each single pulse is taken as the provisional gain for conducting a pulse-position search.

Table 2 shows the results of tests on the effectiveness of using stochastic excitation with partial pulse excitation in conjunction with a transient mode. The segmental signal-to-noise ratio (SNR) is improved and the cepstrum distance is reduced.

Table 3 shows the results of subjective sound quality evaluation of signals coded under conditions 1 and 4 from Table 2. Ten sentences were heard by 16 listeners, who evaluated the sound quality on a five-point scale. The improvement, measured in terms of the average opinion score, was 0.4. There are significant improvements for a male voice. Subjectively, the listeners reported that the noise was lower and consonant sounds clearer with the improved coding algorithm.

Table 2 Objective Test Results

Conditions	Partial pulse codebook	Transient mode	Segmental SNR	CD (dB)
1	No	No	7.61	2.43
2	Yes	No	8.09	2.41
3	No	Yes	8.13	2.31
4	Yes	Yes	8.38	2.30

Table 3 Subjective Test Results

Conditions	Female voice	Male voice	Average
4 – 1	+0.27	+0.53	+0.40

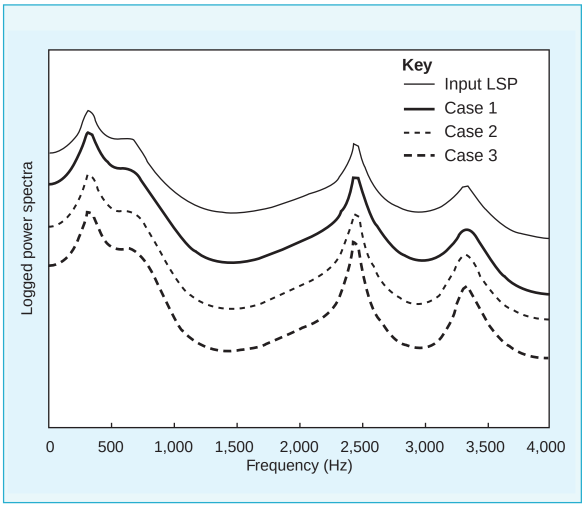

Fig. 3 Examples of spectrum after postfilters.

Error Control under PPS CELP

Since the position synchronization of the stochastic excitation and the position control of codebook vectors depend on previous coding results, the effect of channel errors is a significant consideration. Channel errors have a particularly large impact on stochastic coding when data redundancy using error correction codes is not employed. We investigated two error-resistant modifications. First, we extracted the pitch position synchronization points from the fixed excitation signals. Second, vector selection was centered on the fixed position, and then circular shifted using synchronization point information. These measures brought about an approximately 0.4dB improvement in the segmental SNR under random bit errors, with virtually no signal degradation under error-free conditions.

Post Processing

We introduced a spectral post-processing function that reduces the CELP algorithm characteristic distortion in the demodulated audio signal by emphasizing the peaks and valleys of the output spectrum. Filter coefficients are generally determined by simply squaring the linear prediction coefficients; however, this approach lacks flexibility, and is not easily adapted to various design requirements. We have therefore investigated calculating line spectrum pairs from the linear prediction coefficients, and then compensating the pairs to determine the filter coefficients.[1]

Fig. 3 shows typical characteristics. Compared with the conventional post filtering of Case 1, Cases 2 and 3 emphasize dynamic range at higher frequencies without affecting the low-end frequency response. This approach yields audible improvements in the speech clarity and also permits fine-grained control over the sound quality of demodulated audio signals.

The speech coding technology method presented here combines a number of techniques to achieve substantial incremental improvement in both subjective and objective measures of sound quality. These improvements also reduce processor and bandwidth requirements, promising a substantial downward impact on telecommunications costs. ❑

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Recent Topics in the ITU-R Relating to Mobile Radio Communications

*by Masayoshi Murotani**

Headquartered in Geneva, Switzerland, the International Telecommunication Union (ITU) is responsible for international regulation and standardization in the telecommunications field. In 1985, the ITU's Radiocommunication Sector (ITU-R) initiated development of the mobile telephone standards underlying the explosive worldwide growth of cellular phone and other mobile radio services. ITU-R's Task Group 8/1, responsible for mobile radio services, is working towards standards for a globally unified terrestrial mobile system with completion targeted for the year 2000. ITU-R is also developing a worldwide mobile communications systems using a network of low earth orbiting satellites (LEO). The ITU-R is concerned with both regulations and standards. Reference 1 describes various activities of the ITU-R related to mobile radiocommunications until 1994. This article presents various developments in this field since 1994.[1]

IMT-2000, a Unified Terrestrial Mobile Telephone System

In 1985, TG 8/1 began working on a unified terrestrial mobile telephone system that would be designed to work with satellite based systems. The project is now called IMT-2000, referring to standards for a 2GHz International Mobile Telephone system to be completed by the year 2000. The use of a single operating frequency band worldwide—a central concept of the system—was agreed to in a weak resolution at the 1992 World Administrative Radio Conference (WARC-92) after long and difficult negotiations. Article S5.388 of the ITU's Radio Regulations allocates the 1,885~2,025MHz and 2,110~2,200MHz bands for the system but does not preclude the use of these bands for other services. In fact, several other applications have been proposed for these frequencies. An unrelated satellite-based mobile telephone system has been planned for the 1,980~2,010MHz and 2,170~2,200MHz bands, and the United States, Europe and Japan are seeking to allocate the terrestrial-use portion of the band to an unrelated terrestrial mobile system.

TG 8/1 has been conducting meetings twice a year, and progress is gradual at best. A meeting in South Korea in 1997 established a procedure to nominate standards for the radio transmission technology portion of the standard, and proposals are now being prepared. Possible candidates are narrow-band TDMA, wide-band TDMA, narrow-band CDMA and wide-band CDMA. Wide-band CDMA appears the most promising. Japan has submitted a proposal based on wide-band CDMA. Unanimously agreeing to a single standard will be a great achievement. While all nations agree in principle to the value of a worldwide standard, deep disagreements remain to be resolved.

The standardization process is arduous. There are more than 700 ITU-R recommendations dealing with standardization of various kinds of radiocommunication systems. None of them are complete.

Issues of intellectual property rights also present a barrier to worldwide standardization. Free use of all patents related to a candidate standard would contribute greatly to building consensus on a unified standard, but such sharing is not possible in the current competitive business environment and the ITU's mandate does not extend to this area.

On the other hand, we have to ask ourselves who really wants to have a worldwide standard. Currently there are three mobile radio systems in the world: the European system, the North American system and the Japanese system. Among them, one system has been adopted in more countries than the other two. The developers of this most popular system would prefer to have their regional system adopted as the *de facto* worldwide standard. The regional standardization bodies are highly influential, which complicates the ITU's task of consensus-building. An early solution is unlikely in the opinion of the author, who has been involved in ITU activities for many years.

Another important aspect related to the IMT-2000 is an anticipated shortage of frequency spectrum. The available frequencies cannot satisfy the growing demand for multimedia-capable wideband mobile communication systems. The next World Radiocommunication Conference

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(WRC) in 1999 will consider spectrum and regulatory issues for advanced mobile applications in the context of IMT-2000, noting that there is an urgent need to provide more spectrum for the terrestrial component of such applications and that priority should be given to terrestrial mobile spectrum needs (see WRC-97 Resolution 721).

Mobile Communications by Satellite

Recently various companies in the United States and Europe are promoting plans for mobile radiocommunication networks with a global coverage using low earth orbiting satellites (LEO). Two types of networks are proposed. One uses the frequency bands below 1GHz and is called "Little LEO" because it is mainly used for low-speed message communication (such as paging) in a low frequency band. The other uses the 1~3GHz band and is called "Big LEO" because it is used for high-speed communication including voice in a higher frequency band.

Several projects are underway for Little LEO networks. One serious problem is that very few frequency bands are available for the mobile-satellite service in the bands below 1GHz. In order to expand available frequency bands, studies have been actively carried out on technologies for using the bands without giving unacceptable interference to other services sharing the bands. One example is Dynamic Channel Activity Assignment System (DCAAS). In this system, the spectrum usage at the surface of the Earth is continuously monitored by satellites and only those frequencies which are not used will be used by satellites. At the WRC-97, one nation proposed the application of DCAAS to the 148~149.9MHz band which is now used for mobile land services. This proposal was rejected.

Some proposals recommend sharing television broadcasting bands (470~582MHz and 582~960MHz) and radio broadcasting (45~70MHz, 88~108MHz and 170~240MHz) with mobile satellite communication services but the broadcasting industry unanimously opposes this. The author regrets that the opposing interests have not discussed the issues face to face in the same room, since detailed discussion is needed to reach a consensus.

WRC-97 decided that studies on this issue should continue, and the proposal to share broadcasting bands--previously off limits--reflects the strength of the demands for the satellite-based mobile telephone services.

Satellite Based Mobile Telephone Services in the 1-3 GHz range and their Feeder Links

One of the major decisions at the 1995 World Radiocommunication Conference (WRC-95) was the allocation of frequency bands for the feeder links of satellite-based mobile telephone services. The downlinks of these services will use 6,700~7,075MHz, 15.4~15.7GHz and 19.3~19.6GHz. The uplinks will occupy the 5,091~5,250MHz, 15.45~15.65GHz, 19.3~19.6GHz and 29.1~29.4GHz bands. The 15.45~15.65GHz and 19.3~19.6GHz bands are for sharing as uplinks and downlinks. The frequency sharing situations have become very complicated in other allocated bands. Frequency sharing criteria have been established for each case. One example is the 6,700~7,075MHz band which is shared by microwave radio relay systems for fixed terrestrial services. Evaluating interference of a large number of nongeostationary satellites on terrestrial radio-relay systems is difficult, although Japan has gone as far as calculating the flux-density at the Earth's surface due to satellite transmissions considering the space-diversity reception widely used in radio-relay systems.

Nations at WRC-95 agreed to allocate 1,980~2,010MHz and 2,170~2,200MHz bands in the year 2000 to provide service links between satellites and mobile user terminals. Protests from developing countries, which will have to change the operating frequencies of their radio-relay systems, was overcome through offers of technical cooperation from the advanced nations.

Frequency sharing criteria between the mobile-satellite service and terrestrial radio services are generally determined in relation to fixed services such as radio-relay systems. However, the 1,492~1,525MHz band allocated to the mobile-satellite service in Region 2 (North and South America) is one exception. WRC-95 determined that the coordination threshold in terms of the power flux-density levels at the surface of the Earth for space stations in the mobile-satellite (space-to-Earth) service, with respect to the land mobile service use within the territory of Japan, shall be -50dB (W/m^2) in any 4kHz band for all angles of arrival (see Article S5.384A of the Radio Regulations). This provision takes into account the wide use of this band in Japan for the terrestrial mobile communications including portable telephones. This is an important provision from the Japanese viewpoint. On the other hand, from an international perspective, it reflects the current complicated spectrum usage.

Preparation for WRC-97 and its Decisions

Further debate concerning additional allocation of frequency bands in the 1~3GHz range took place in the preparatory phase for WRC-97, which was held in October and November 1997. Discussions continued from the ITU World Telecommunication Forum on Global Mobile Personal Communications by Satellite (GMPCS) which was held in 1996 and resolved that competitive policy should be introduced also in GMPCS. Sufficient frequency allocation is essential to support competition; however, actual allocation is opposed by users of current allocations, since the new allocations inevitably affect the quality of services in the existing allocations.

Congestion in the spectrum usage is first reflected in the advance notices which are submitted to the ITU in order to negotiate with the affected nations several years before satellites are actually launched. As of May 1997, as many as 243 notifications had been published for satellite based mobile communication systems for the 1~3GHz band. It is impossible for all of these projects to be actually implemented. Many may be so-called “paper satellites” which are not intended for actual launch. Nevertheless, the situation is difficult. One forecast estimates that the spectrum demand for the mobile-satellite services in the 1~3GHz range will be as large as 500MHz in the year 2010. In contrast, the current allocation for the year 2000 allows only 200MHz in Regions 1 (Europe and Africa) and 3 (Asia and Pacific) and 280MHz in Region 2 (North and South America).

Spectrum demand is also related with how many different systems of mobile communication networks using non-GSO satellites can share the same frequency bands. It is generally recognized that systems using FDMA or TDMA cannot coexist with systems using CDMA when the service areas are the same and the frequency bands are also the same. If both systems use CDMA, frequency sharing seems feasible subject to certain conditions. This kind of constraint seems to be an intrinsic problem of non-GSO mobile-satellite systems.

Additional frequency allocations at WRC-97 for the service links of the mobile-satellite service were modest, and the frequency shortage is expected to continue.

Important progress was made prior WRC-97 with respect to frequency sharing between the satellite-based mobile services and the fixed service radio-relay systems in the 1~3GHz band. In 1995, Article ITU-R IS.1141 and IS.1142 established emitted maximum power levels for mobile-service satellites for the purpose of coordinating with fixed services. In general, the recommendations expressed the satellite power over a 4kHz reference band; however, Article ITU-R F.1246, approved in 1997, recommends a 1MHz reference band for digital fixed service systems and combined 1MHz and 4kHz bands for analog fixed service systems. The article also states that the level in the 1MHz reference band should be 24dB higher than the current prescribed level for the 4kHz band and the level in the 4kHz band should be 6dB higher than the current level. Article ITU-R F.1246 will facilitate coordination to a certain degree. Detailed interference assessments carried out in Japan made a great contribution to the establishment of this recommendation.

One interesting aspect which has emerged in the study concerning feeder links is the interpretation of Article S22.2 of the Radio Regulations which states that a non-GSO satellite shall not cause harmful interference to GSO satellites in fixed-satellite services. In view of the increasing number of non-GSO satellites in recent years, it has become a heated issue how to apply Article S22.2 of the Radio Regulations. One interpretation is that GSO satellites have an absolute priority over non-GSO satellites, including future GSO satellites, on which no coordination requirements would be imposed. Another interpretation is that acceptable interference levels should be discussed by all parties concerned and non-GSO satellites should cease to operate only when the interference to existing GSO satellites exceeds the allowable level. Although this issue continues to be debated, the second interpretation has been prevailing since WRC-97.

New Technologies for Fixed Service Applications

Fixed service means radiocommunications between fixed points and mobile service means radiocommunications involving mobile stations. While the definitions are different, the relevant technologies and applications are gradually merging. We therefore choose to include recent topics in fixed applications.

Fixed Services Using Non-Geostationary Satellites

Most prior fixed-service radiocommunication systems have employed geostationary satellites. At WRC-95, the United States submitted a proposal for a fixed-service system using non-geostationary satellites. The proposed system would employ as many as 840 of these satellites operating in the 20/30GHz bands to establish a worldwide commercial information network. The U.S. presentation caused something of an uproar since the topic was not a part of the agenda established two years before, but the other nations agreed to consider the proposal and ended up allocating the 18.8~19.3GHz band for downlinks and 28.6~29.1GHz band for uplinks. This project is now being managed by U.S. companies.

Eight hundred forty satellites seems excessive, and unofficial reports suggest the number has been reduced to about 200. Earth stations for the system must be engineered to automatically track the moving satellites.

The WRC-97 received a similar proposal from France which plans to implement non-GSO fixed-service system in other frequency bands including the 12GHz band which is now being used for the satellite-broadcasting services.

Frequency sharing between non-GSO fixed-service systems, geostationary fixed-service systems, geostationary direct satellite broadcasting services and and terrestrial services is a serious problem. Provisional requirements for controlling the mutual interference have been laid down in the Radio Regulations, but much work remains to be done. The ITU-R has created a special Task Group to study this matter and the work is under way.

Fixed Services Using Platforms in the Stratosphere

The January 1997 meeting of ITU-R Study Group 9 (fixed service) received a proposal from the United States to launch balloons at an altitude of 23km in the stratosphere for use as repeaters in the 47.2~50.2GHz (millimeter-wave) band. Each of these balloon-lofted repeaters could support fixed service regions of up to several hundred km in radius. Mobile communications would not be possible at such high frequencies, and the U.S. chose this frequency since lower-frequency bands—which would have been preferred—were unavailable. The system is feasible due to development of high efficiency ion engines that can be used to control the platform position. It was reported that solar cells can provide sufficient power for communication and position control.

Representatives at the meeting initially agreed to classify the new system as terrestrial, then later officially categorized the system as high altitude platform stations (HAPS), incorporating the definition into the Radio Regulations. The 47.2~47.5GHz and 47.9~48.2GHz frequency bands were designated for use by HAPS providing fixed services.

The proposed system still has many technical difficulties to overcome and the feasibility of a several hundred km radius service area at 47GHz remains to be demonstrated. Even if technical difficulties are overcome, the commercial viability of the venture is uncertain, and the project is going forward at some risk to its investors.

Conclusion

The ITU-R is now at a most crucial stage in establishing IMT-2000 as a global standard for mobile communications. Several satellite-based mobile communication systems are currently being implemented and various technical standards have been established, but significant issues, including the shortage of spectrum are still unresolved. Meanwhile, fixed-service radiocommunication projects are under way to serve similar markets. Technologies are combining and the market is becoming more competitive. ❑

Reference

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