PAPER Special Issue on the Latest Development of Telecommunication Research

A Wireless Multimedia Communication System Using Hierarchical Modulation

Yasushi SAKAMOTO†, *Student Member*, Masakazu MORIMOTO†*, Minoru OKADA†, *and* Shozo KOMAKI†, *Members*

SUMMARY This paper proposes a new wireless multimedia communication system based on hierarchical modulation, which gives unequal transmission reliability corresponding to the sensitivity to the transmission errors. In order to achieve high quality multimedia communication in a band-limited and time-variant fading channel, the proposed scheme changes the modulation scheme according to the contents of information. Numerical analysis shows that the proposed system is an effective high-quality and high-speed multimedia transmission technique in fading channel.
key words: *mobile communication, hierarchical modulation, wireless agent*

1. Introduction

Recently, there has been an increasing demand for multimedia transmission, such as the transmission of text, data, voice and images, in mobile communication systems. Since multimedia information, include image, has huge amount of data, high speed digital transmission is required to realize multimedia transmission.

However, in mobile communication systems, since the number of user is rapidly increasing while the frequency bandwidth for the mobile system is strictly limited, the available frequency bandwidth for individual users is also severely limited. Moreover, since multipath fading, shadowing, co-channel interference and so on degrade the transmission reliability, it is difficult to realize highly reliable and high speed digital transmission.

In multimedia information, a difference in kind of information makes a difference in a required QoS (Quality of Service), such as a required transmission rate and a required transmission reliability. Bandwidth efficient and reliable multimedia communication system could be achieved by changing the transmission rate and reliability according to the required QoS. However, there is no study on a mobile communication system which selects wireless transmission forms according to a required QoS.

Hierarchical transmission system has widely been studied as an effective solution to realize efficient image transmission over mobile communication systems [1], [2]. Hierarchical transmission system, composed of hierarchical source coder and corresponding channel coder, divides the information into several layers according to their significance, and transmits each layers with different reliability according to the layers, to gives better received quality. We extend this system to transmission of mixed media in which text and image are mixed, over mobile communication system.

In this paper, we propose a new mixed media mobile communication system, which selects wireless modulation format according to the required transmission rate and transmission reliability of information. In the proposed system, wireless agents in the base station and mobile terminal divides kind of information and selects wireless transmission forms automatically.

We show the performance of the proposed system in case of transmission of image and in case of transmission of mixed media by the computer simulation results, and the availability of the proposed system.

2. Multimedia Wireless Transmission System Using Wireless Agent

2.1 System Model

Figure 1 shows the block diagram of the proposed multimedia wireless transmission system. A mobile terminal is connected to the World-Wide Web (WWW) server through a wireless connection. In this system, the wireless agents, which run on the base station and mobile terminal, choose the modulation scheme according to the type of information. By employing wireless agents, wireless multimedia data transmission becomes more efficiently.

When the mixed media information arrives at the base station, the wireless agent divides the mixed data to the image and text data. Text and control data require error free transmission while they are not sensitive to transmission delay. On the other hand, image is sensitive to transmission delay while they are not sensitive to transmission errors. The wireless agent chooses a modulation scheme according to requirement of transmission data considering user's request about transmission time, and so on.

Manuscript received April 13, 1998.
Manuscript revised July 1, 1998.
†The authors are with the Faculty of Engineering, Osaka University, Suita-shi, 565–0871 Japan.
*Presently, author is with the Faculty of Engineering, Himeji Institute of Technology, Himeji-shi, 671–2201 Japan.

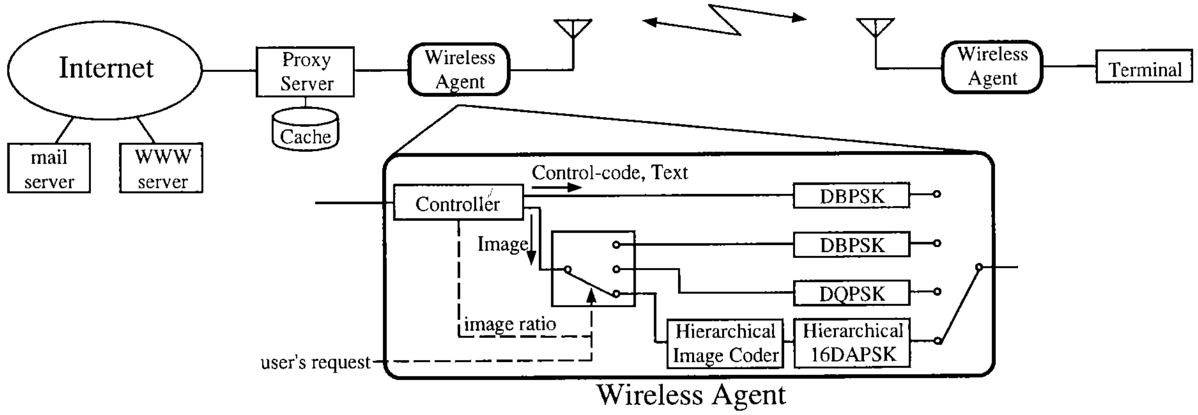


Fig. 1 System model.

2.2 A Hierarchical Image Transmission System

Now, we discuss the image transmission scheme of the multimedia wireless transmission system. We employ a hierarchical image transmission system for a image transmission part of the proposed system. In a hierarchical image transmission system, hierarchical image coder divides image data into several layers according to their error sensitivity and hierarchical modulator transmits each layer with different reliability according to the significance of layer. A hierarchical image transmission scheme is effective for wireless image transmission because the error sensitivity of encoded image data bit is drastically different each other.

Figure 2 shows the block diagram of the employed hierarchical image transmission system. In this system, image data is encoded by the ADCT (adaptive discrete cosine transform [4]) image coder. The ADCT is one of the most effective image compression technique, and is free from error propagation because of fixed length compression.

After ADCT coding, this system divides encoded image data into two layers according to its error sensitivity. In ADCT encoded image, we call information bits of which incorrect receipt degrades received image quality seriously "Base Layer (layer1)," on the other hand information bits of which incorrect receipt degrades received image quality little but which are necessary to receive high-quality image as "Enhancement Layer (layer2)."

Then, the divided image data is transmitted by the hierarchical 16DAPSK modulation [5]. Since the differential detection scheme is employed at the receiver, the receiver can demodulate the received signal in a fast fading environment. Figure 3 shows a constellation diagram of the hierarchical 16DAPSK signal, where H and L are amplitude of outside and inside constellations, respectively. In this figure, the base information bits select one of the 4 clusters, and the enhancement information bits select one of the 4 constellation points within se-

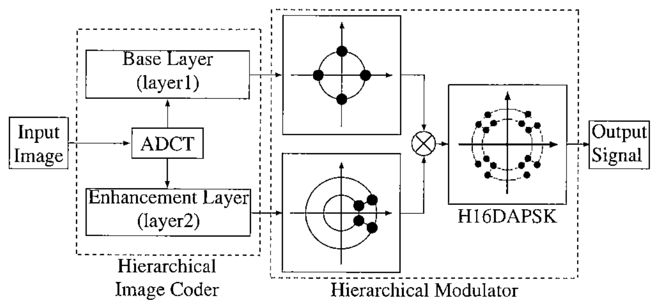


Fig. 2 Hierarchical 16DAPSK based image transmission system.

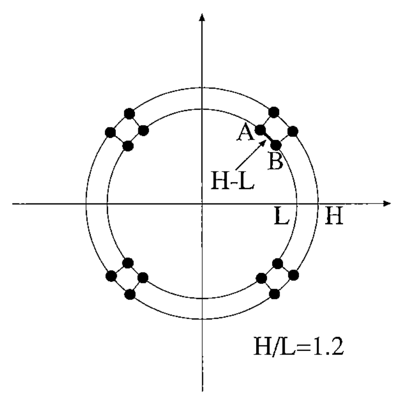


Fig. 3 Constellation diagram of the hierarchical 16DAPSK signal.

lected cluster. In this figure, the distance between the points A and B is set to be H-L. In this assumption, we can uniquely decide the constellation with one parameter H/L. In this paper, we suppose H/L 1.2. In this case, the hierarchical 16DAPSK gives worse bit error rate performance to the enhancement layer and better performance to the base layer as compared with the conventional 16DAPSK. Therefore, when channel quality becomes worse, the hierarchical 16DAPSK gives better received image quality performance than the conventional 16DAPSK since the hierarchical 16DAPSK can

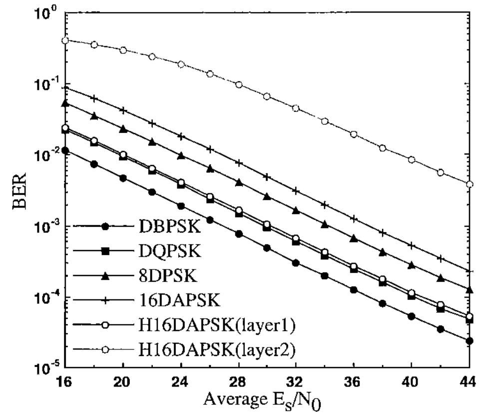


Fig. 4 BER performance against the average E_s/N_0.

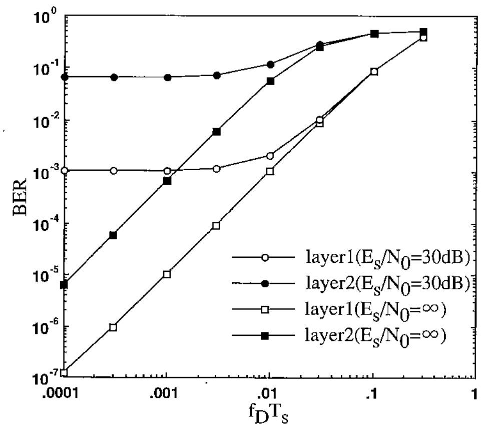


Fig. 5 BER performance against f_DT_S.

still transmit base layer correctly, namely, the hierarchical modulation gives graceful degradation.

Figure 4 shows the BER (Bit Error Rate) performance of hierarchical 16DAPSK, 16DAPSK, 8DPSK (Differential Phase Shift Keying), DQPSK (Differential Quadrature Phase Shift Keying), and DBPSK against the average E_s/N_0 of Rayleigh fading channel. In this figure, information are transmitted over a Rayleigh fading channel which has normalized maximum Doppler frequency $f_DT_S = 0.001$. This figure shows that the hierarchical modulator improves the BER of base layer transmission at the sacrifice of enhancement layer's BER.

Figure 5 shows the BER performance of the hierarchical 16DAPSK against f_DT_S, in a Rayleigh fading channel at $E_s/N_0 = 30$ dB and $E_s/N_0 = \infty$ respectively. The BER performance of "layer1" and "layer2" do not degrade when f_DT_S is less than 0.003 at $E_s/N_0 = 30$ dB.

3. Simulation Results

In this section, we show simulation results of the received image quality and received mixed information quality performance of the proposed system in a Rayleigh fading channel at $f_DT_S = 0.001$.

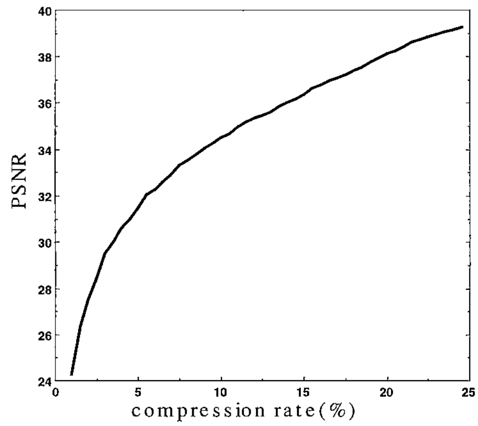


Fig. 6 Reconstructed ADCT image quality against the compression rate of "girl."

In the following, we evaluate PSNR (Peak Signal to Noise Power Ratio) as a received image quality criterion. PSNR [dB] of 256-level monochrome image is given by

$$\mathrm{PSNR} = 10\log_{10}\frac{255^2}{\frac{1}{L_xL_y}\sum_{x=0}^{L_x}\sum_{y=0}^{L_y}(S_{x,y}-S'_{x,y})^2}$$

where L_x and L_y are width and height of the image, and $S_{x,y}$ and $S'_{x,y}$ represent the intensities of the original and reconstructed pixels, respectively. In the simulation, we use a SIDBA standard image file named "girl" as image data included in mixed information. Figure 6 shows the reconstructed ADCT image quality against the compression rate of "girl." The PSNR decreases as the compression rate decreases.

3.1 Received Image Quality

3.1.1 Under Same Transmission Time Condition

In mobile communication systems, a difference in a received point makes a difference in the average channel E_s/N_0. Here, we analyze the performance of the proposed system against the average channel E_s/N_0 under condition that transmission time is fixed. First, Fig. 7 shows the PSNR performance of the proposed system against the average channel E_s/N_0. For comparison, the performance of conventional 4 systems are also shown in this figure. The compression rates of these systems are shown in Table 1. Since all the systems use the same bandwidth, the compression rates are different from each other as shown in Table 1. This figure shows that the hierarchical 16DAPSK scheme gives better performance than the other modulation schemes when the average E_s/N_0 is greater than 24 dB, and DBPSK scheme gives better performance than the other modulation schemes when the average E_s/N_0 is less than 24 dB. But, even if the average E_s/N_0 is less than

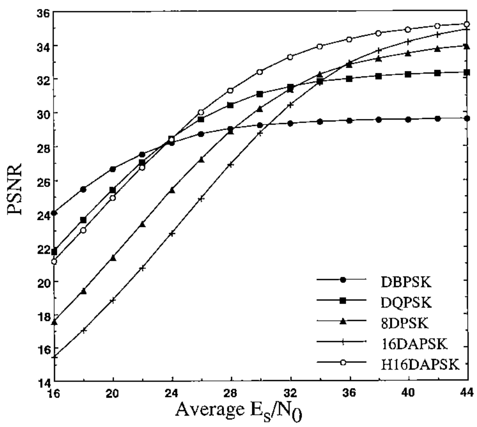


Fig. 7 PSNR performance against the average channel E_s/N_0.

Table 1 Compression rate and PSNR.

Mod. Scheme	Comp. Rate
H16DAPSK	12.5%
16DAPSK	12.5%
D8PSK	9.375%
DQPSK	6.25%
DBPSK	3.125%

24 dB, the hierarchical 16DAPSK scheme does not give bad performance.

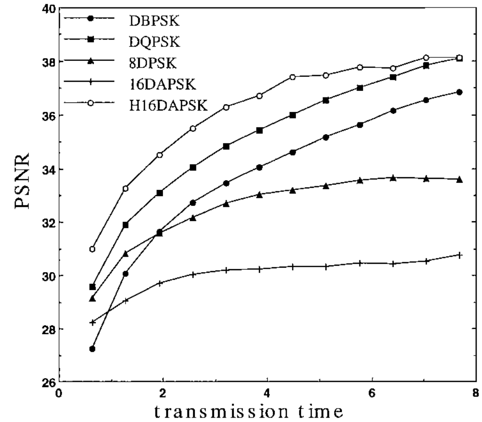
3.1.2 Under Same Compression Rate Condition

Transmission time may be limited to the value which user requires and so on. Here, we analyze the performance of the proposed system against transmission time. Figures 8 (a) and 8 (b) show the PSNR performance against the transmission time, in a Rayleigh fading channel at $E_s/N_0 = 30$ dB and 25 dB, respectively. We suppose that the channel bandwidth is 16 kHz. This implies that it will take 1 second to transmit the 12.5% compressed "girl" image data with 16DAPSK modulation scheme and 4 seconds with DBPSK modulation scheme.

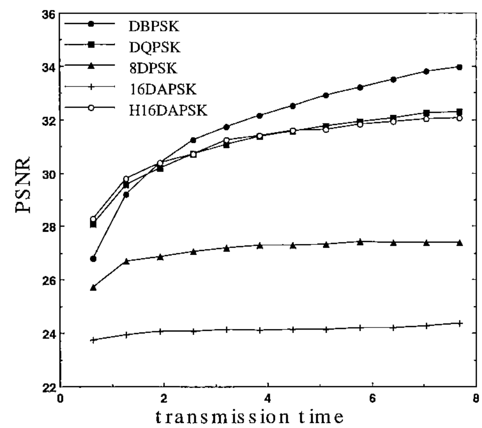
Figure 8 (a) shows that the hierarchical 16DAPSK scheme gives better received image quality performance than other modulation schemes when average E_s/N_0 is 30 dB.

On the other hand, Fig. 8 (b) shows that the hierarchical 16DAPSK scheme gives better performance than other modulation schemes at short transmission time, and that the DBPSK scheme gives better performance than other modulation schemes at long transmission time. However, the PSNR performance of 8DPSK and 16DAPSK become worse, because they can not transmit information correctly in a Rayleigh fading channel at $E_s/N_0 = 25$ dB.

In the case that the transmitter knows the E_s/N_0, we can further improve the PSNR performance by changing the transmitter scheme according to the QoS requirement and E_s/N_0. On the other hand, the proposed system is still effective when E_s/N_0 is not known at the transmitter. For example, suppose that we choose the hierarchical 16DAPSK scheme when required transmission time is less than 2 seconds and DBPSK scheme when required transmission time is more than 2 seconds. In this case, we can ensure the PSNR performance more than 28 dB at $E_s/N_0 = 25$ dB and more than 31 dB at $E_s/N_0 = 30$ dB.



(a) E_s/N_0=30dB



(b) E_s/N_0=25dB

Fig. 8 PSNR performance against the transmission time.

3.2 Received Mixed Information Quality

Now, we suppose 64 kbytes of data which contains text and still image. We also suppose that the available bandwidth is 16 kHz. This implies that it will take 8 second to transmit the mentioned information with 16DAPSK modulation scheme and 32 seconds with DBPSK modulation scheme. The proposed system transmits text with DBPSK fixedly and still image with modulation scheme which is selected according to user's demand and so on. Here, we analyze the performance of the proposed system in the cases that still image is transmitted with each modulation scheme. We

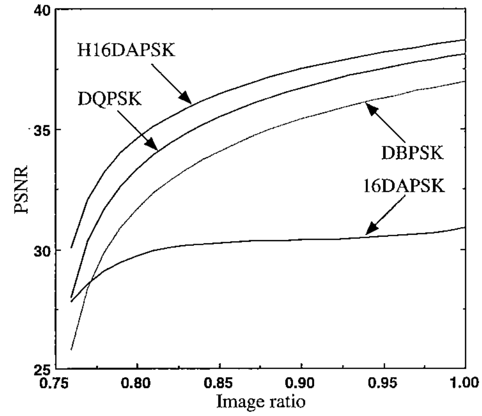


Fig. 9 PSNR performance against the image ratio (available time = 8 sec).

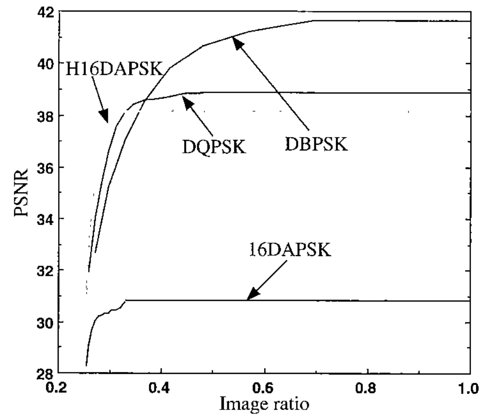


Fig. 10 PSNR performance against the image ratio (available time = 24 sec).

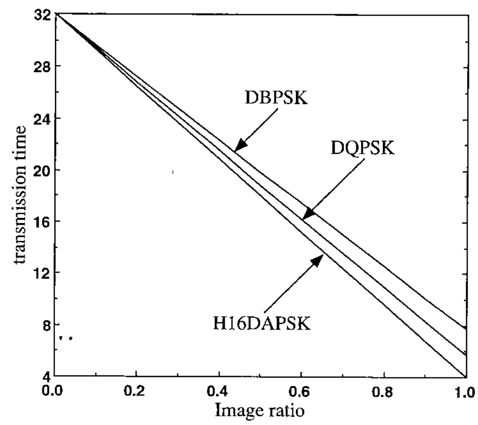


Fig. 11 Transmission time against the image ratio (required PSNR = 37 dB).

call a ratio of information bits of image to transmitted information bits "image ratio." We suppose that the average channel E_s/N_0 is 30 dB and $f_DT_s = 0.001$.

3.2.1 Under Same Available Time Condition

Available time for transmission may be limited by user's demand and so on, regardless of what is transmitted. Here, we analyze the performance of the proposed system under condition that available time is limited. Figures 9 and 10 show the PSNR performance against the image ratio, in the situation that available time for transmission of mentioned 64 kbytes of data is 8 seconds and 24 seconds, respectively.

Figure 9 shows that the hierarchical 16DAPSK scheme gives better received image quality performance than other modulation schemes. On the other hand, Fig. 10 shows that the hierarchical 16DAPSK scheme gives better performance than other modulation schemes when the image ratio is less than 0.34, DQPSK scheme gives better performance than other modulation schemes when the image ratio is more than 0.34 and less than 0.37, and DBPSK scheme gives better performance than other modulation schemes when the image ratio is more than 0.37. The reason why the hierarchical 16DAPSK scheme and DQPSK scheme give constant performance when the image ratio is more than 1/3 and 1/2, respectively, is that since they transmit all information within available time, compression of image data is not necessary. Therefore, we can further improve the PSNR performance by changing transmission schemes of image transmission according to the image ratio.

3.2.2 Under Same Received Image Quality Condition

Received image quality may be required more than transmission time. Here, we analyze the transmission time of the proposed system to give required image quality. Figure 11 shows the transmission time for transmission of mentioned 64 kbytes of data against the image ratio, in the situation that required PSNR is 37 dB. This figure shows that the hierarchical 16DAPSK scheme gives shorter transmission time than other modulation scheme. However, even if we have time enough for 16DAPSK scheme to transmit all information, it can not give mentioned required PSNR, because it can not transmit information correctly.

4. Conclusion

In this paper, we have proposed a new intelligent multimedia wireless transmission system, and investigated the transmission performance of the proposed system in a Raylaigh fading channel. Computer simulation results show that the proposed system is an effective high-quality and high-speed multimedia transmission system in a fading channel.

In this paper, the channel coding and the other source coding schemes are not taken into account, and further investigation is required.

References

[1] M. Morimoto, M. Okada, and S. Komaki, "A study on a hierarchical image transmission system in a Rayleigh fading channel," IEICE Technical Report, CS96-29, RCS96-22, May 1996.
[2] M. Morimoto, M. Okada, and S. Komaki, "A hierarchical image transmission system for multimedia mobile communication," IEICE Trans. Commun., vol.E80-B, no.5, May 1997.
[3] T. Suzuki and T. Mizuno, "Multiple-symbol differential detection for differential encoded amplitude modulation signals and its application to 16DAPSK," IEICE Trans., vol.J77-B-II, no.12, pp.739–748, Dec. 1994.
[4] W.H. Chen and C.H. Smith, "Adaptive coding of monochrome and color images," IEEE Trans. Commun., vol.25, pp.1285–1292, Nov. 1977.
[5] Y. Sakamoto, M. Morimoto, M. Okada, and S. Komaki, "A hierarchical 16DAPSK based image transmission system for mobile communications," Proc. 1997 IEICE General Conference, B-5-284, p.671, March 1997.

Yasushi Sakamoto was born in Osaka, Japan, on December 29, 1974. He received the B.E. degrees in Communications Engineering from Osaka University, Osaka, Japan, in 1997. He is currently a master course student at Osaka University. His research interest includes mobile and multimedia communications.

Masakazu Morimoto was born in Osaka, Japan, on December 6, 1971. He received B.E. and M.E. degrees in Electrical Engineering from Osaka University in 1994 and 1996, respectively, and Dr.Eng. degree in Communications Engineering from Osaka University in 1998. He is currently a research associate in the Department of Computer Engineering, Himeji Institute of Technology. Dr. Morimoto is a member of IEEE. His current research interests are in image and video communications.

Minoru Okada was born in Tokushima Japan, on March 4, 1968. He received the B.E. degree in communications engineering from University of Electro-Communications, Tokyo, Japan, in 1990, and the M.E. and Ph.D. degrees in communications engineering from Osaka University, Osaka, Japan, in 1992 and 1998, respectively. He is currently an assistant professor in the department of communications engineering at Osaka University. His current interest is in radio communications systems. He is a member of IEEE.

Shozo Komaki was born in Osaka, Japan, in 1947. He received B.E., M.E. and Ph.D. degrees in Electrical Communication Engineering from Osaka University, in 1970, 1972 and 1983 respectively. In 1972, he joined the NTT Radio Communication Labs., where he was engaged in repeater development for a 20-GHz digital radio system, 16-QAM and 256-QAM systems. From 1990, he moved to Osaka University, Faculty of Engineering, and engaging in the research on radio and optical communication systems. He is currently a Professor of Osaka University. Dr. Komaki is a senior member of IEEE, and a member of the Institute of Television Engineers of Japan (ITE). He was awarded the Paper Award and the Achievement Award of IEICE, Japan in 1977 and 1994 respectively.