A DS UWB Transmission System for Wireless Telemedicine

Chin-Feng Lin, and Ching Yi-Li

Department of Electrical Engineering
National Taiwan-Ocean University

Pei-Ning Road, Keelung, Taiwan ROC
lcf1024@mail.ntou.edu.tw

Abstract:- In this paper, we propose a direct-sequence ultra-wideband (DS UWB) transmission system for wireless telemedicine system. An essential feature of this system is that it offers larger power and schemes providing significant error protection for the transmission of medical information that requires higher quality of service (QoS). To realize maximum resource utilization, or minimum total transmission power, we also include an M-ary binary offset keying (MBOK) strategy into the system. Thus, in the proposed medical system, high power, a long length MBOK code, and scheme providing significant error protection schemes are employed for the transmission of medical messages that require a stringent bit-error rate (BER). In contrast, low power, short length MBOK codes, and less capable error protection schemes are provided for messages that can tolerate a high BER. A simulation is carried out to verify the proper functioning of the proposed system in a practical wireless telemedicine scenario.

Key-Words: - Wireless Telemedicine, DS UWB, power assignment mechanism, unequal error protection, MBOK.

1 Introduction

Telemedicine performed by employing a high-speed and robust advanced wireless communication system, such as the healthcare system can provide ubiquitous emergent or health-monitoring medical services at any time. We study the characteristic of transmission media in medicine system, and design various telemedicine systems by using advance wireless communication technique. The second generation (2G), third generation (3G), and fourth generation (4G) are adopted as a transmission platform in emergency telemedicine and healthcare system [1-11]. With regard to the areas of ocean, mountain, remote area, forest and desert as well as aircraft in the sky, the mobile satellite communication system is suitable for the communication environments of these areas [12-13]. Bluetooth, and wireless local area network (WLAN) are general transmission platform for wireless indoor telemedicine [14-16]. The transmission medical media for these telemedicine systems include electrocardiogram (ECG), medical image, and medical sensor values such as blood pressure and body temperature. The transmission data rates of wireless platform are restrictedly, our effort are toward real time and interactive medical conference. The performance of a mobile telemedicine system that adopts multi-code code division multiple access (CDMA), or satellite wideband CDMA, or orthogonal frequency division multiplexing (OFDM), or direct-sequence ultra-wideband (DS UWB) techniques has been scrupulously studied in our earlier work [17-25]. In [22], we discuss a power control scheme in an equal error protection DS UWB wireless telemedicine system. In [23], we discuss a DS UWB medical system. In this study, we extend our previous research [22-24] by considering the use of power assignment schemes and M-ary binary offset keying (MBOK) coding strategies in a DS UWB

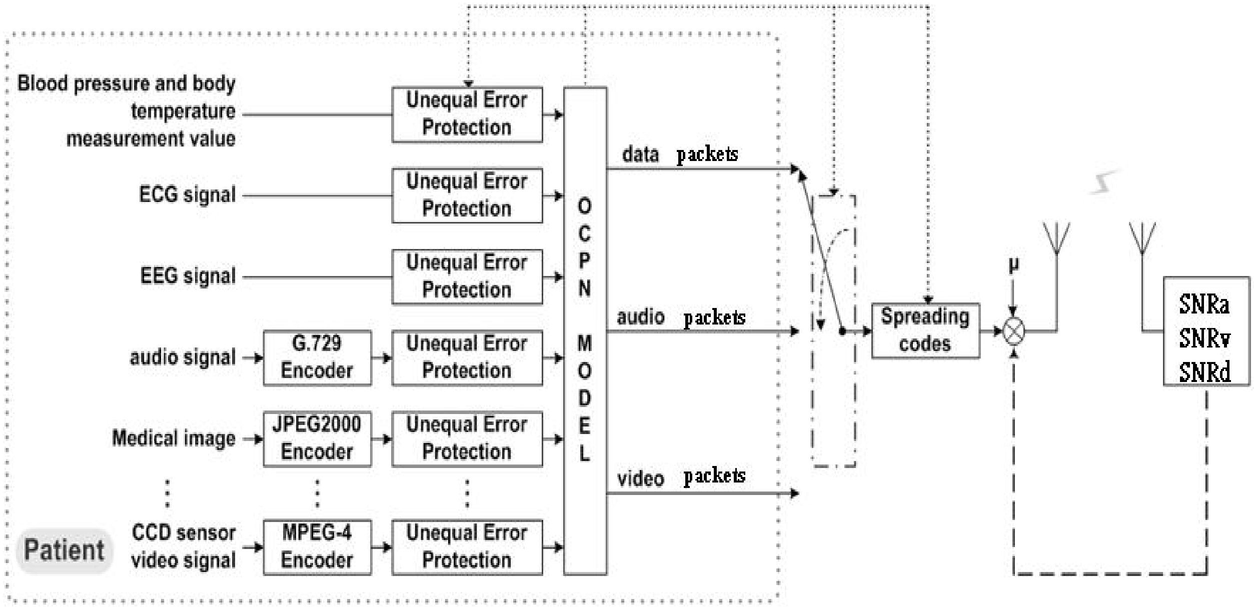

Fig. 1 The proposed DS UWB wireless indoor telemedicine system with power assignment mechanism.

wireless telemedicine system with unequal error protection. In addition, we discuss the relation between the power weighting factor and power saving. Ultra-wideband technology is a new technology for short-range high-speed wireless multimedia communication systems. The specifications corresponding to a data rate of 1320 Mbps and transmission range of 10 meters indicate that DS UWB is a suitable candidate with which transmission platforms for a wireless indoor telemedicine system can be developed. A generic definition used in the FCC's First Report [26], which is also widely accepted by the industry, defines a UWB device as any device that can emit signals with a fractional bandwidth greater than 0.2 or a bandwidth of at least 500 MHz at all times. A DS UWB system can operate in two modes, at a transmission bandwidth of 1.368GHz in a 4-GHz low central frequency band and at a transmission bandwidth of 2.763GHz in an 8.2-GHz high central frequency band. There are two kinds of multiple access techniques specified in the UWB standard, OFDM and the direct-sequence code division multiple access (DS-CDMA) UWB technique.

Several MBOK short spreading codes can be selected when employing DS UWB so that different transmission rates can be supported. For instance, in low operating band operation, the use of MBOK code lengths of 24, 12, 6, and 3 can result in transmission bit rates of 28Mbps, 55Mbps, 110 Mbps, and 220 Mbps, respectively. Short MBOK codes with a smaller spreading factor are suitable for high-rate transmissions that require low capability for combating channel fading. Moreover, different convolution codes, K=6, coding rate=1/2, 2/3 and 3/4 can be used based on channel conditions. K is the constraint length for convolution code. For the proposed medical system, we employ a strategy involving high power, and a long length spreading codes strategy, and schemes offering significant error protection for the transmission of medical messages that require a stringent bit-error rate (BER). In contrast, low power, short length spreading codes, and less capable error protection schemes are provided for messages that can tolerate a high BER. This system can not only satisfies the quality of service (QoS) required by a telemedicine system, but also maximizes the transmission bit rate or minimizes the transmission power.

2. A Power Assignment Mechanism for DS UWB Wireless Telemedicine System

A sketch of the proposed DS UWB transport architecture for the wireless indoor telemedicine system is depicted in Figure 1. From this figure we can observe that the wireless indoor telemedicine system under consideration can deal with various types of signals such as (i) blood pressure and body temperature measured with a few bits, (ii) medical information recorded by the electrocardiogram (ECG) device and electroencephalography (EEG) devices, (iii) mobile patients' history, and (iv) G.729 audio signals and MPEG-4 CCD sensor video signals. The processing of pre-recorded medical information requires the synchronous playback of time-dependent medical data based on some pre-specified temporal relations. For this purpose, a model with which temporal constraints among various data objects observable at the time of playback can be specified is needed for a patient. In this regard, a well-known model, which is called the Object Composition Petri Net (OCPN) model, was presented in [27]. An important feature of the OCPN model is that temporal relationships among the various components of a medical document including the types, sizes, throughput requirements, and the duration of their presence, can be illustrated. Based on the OCPN model, the blood pressure, body temperature, ECG and EEG signals of every patient are directly converted to data bit streams. However, audio signals obtained from microphones and CCD sensor video signals should be transformed before being used by the model. In other words, the blood pressure, body temperature, the 108-kbps bit streams for 12-channel ECG signals and the 262.114-kbps bit streams for 64-channel EEG signals of every patient are directly converted to data bit streams. However, a G.729 encoder should be employed to compress the 64-kbps audio signals to 8-kbps audio bit streams, an MPEG-4 encoder is adopted to convert the 147.456-Mbps video signals into 15-Mbps video bit streams, and the JPEG2000 is used to compress the 3640-kbits X-ray medical image signal to form a 128-kbits image bit stream. In our transport architecture, the data, audio, and video bit streams compose data, audio, and video packets, respectively. Since the OCPN model can specify the throughput resulting from the transmission of concurrent multimedia objects, the sum of the data, audio, and video packets can be calculated. Usually, in a wireless medical system , the QoS is different for various messages. Here, we assume that the acceptable BERs for data, audio, and video packets are 10^{-7} , 10^{-3} , and 10^{-4} , respectively [4]. For this purpose, it is assumed that the system can perform unequal error protection, as shown in Figure 1. To satisfy the differentiated QoS, we adopt power assignment strategies and different transmission techniques for different types of packets. Specifically, we provide high transmission power, long spreading codes with a length of 24, and strategies for providing significant error protection strategies for data packets that require a low BER. In contrast, low power, short length spreading codes, and less capable error protection strategies are used for the transmission of audio and video packets that can tolerate less stringent BERs. The transmitting signal of the *m*-th kind bit stream in the baseband, $s_m(t)$, is expressed as

$$s_m(t) = \sqrt{2\mu P} a_m(t) b_m(t) \quad (1)$$

In (1), *P* is the constant transmission power; μ, the weighting factor of the transmission power, $b_m(t)$, the data signal comprising a sequence of rectangular pulses of duration *T*; and $a_m(t)$, the MBOK code described in the DS UWB standard [27] with optional length L=24, 12, 6, 4, 2, 1. L is the length for MBOK codes. The signal received at the input to the matched filter in the mobile receiver can be represented as

$$r(t) = \sum_{l=1}^{M} \beta_l \sqrt{2\mu P} a_m(t-\tau_l) b_m(t-\tau_l) + n(t) \quad (2)$$

where *n*(*t*) is the additive white Gaussian noise (AWGN) process with two-sided power spectral density ($N_0/2$). It is assumed that τ_l can be locked to the *l*-th path as a reference path between the transmitter and its corresponding receiver for the m-*th* kind bit stream. β_l is the multi-path gain of the *i-th* path. The received signal to noise ratio (SNR) is given by

$$SNR = \frac{E\{[\sum_{l=1}^{M} \beta_l \sqrt{2\mu P} a_m(t-\tau_l) b_m(t-\tau_l)]^2\}}{E\{n^2(t)\}} \quad (3)$$

Thus, the power assignment mechanism can be summarized as follows:

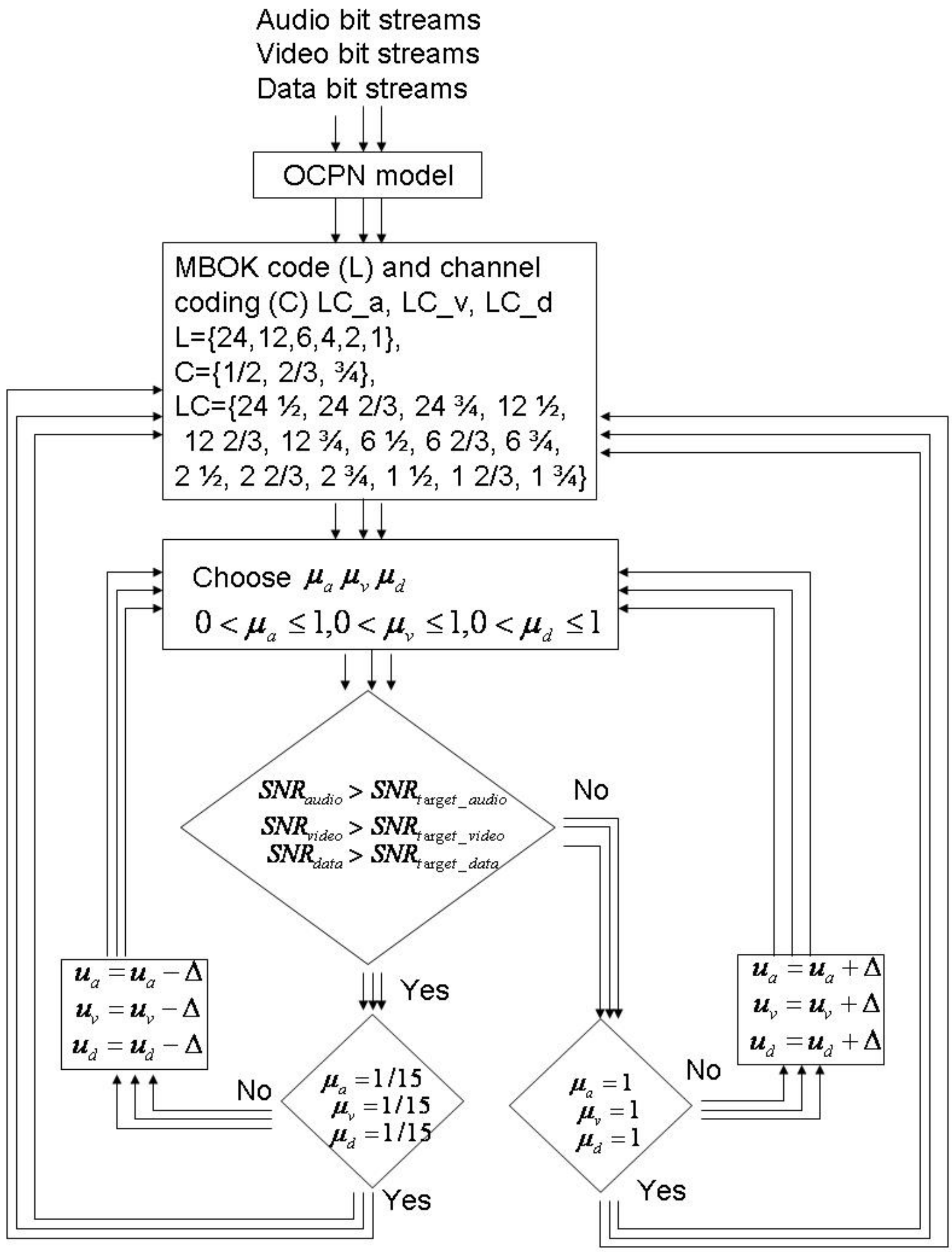

Figure 2 The flow of the proposed power assignment mechanism.

Step 1: Based on the information at the OCPN output, evaluate the throughputs of the data, audio, and video messages for real-time transmissions.

Step 2: Select appropriate parameters for unequal error protection and proper modulation modes so that the requirements for real-time transmissions in a wireless medical network can be fulfilled.

Step 3: Assign the original transmission power weighting factor, μ , $0 < \mu \le 1$, for the data, audio, and video packets.

Step 4: Measure the received signal-to-noise interference ratio (SNR) for the data, audio, and video packets.

Step 5: For each type of packet, if the measured SNR of the received signal is larger than the threshold SNR for the required BER, then the transmission power weighting factor is updated as $\mu = \mu - \Delta$, and Step 4 should be performed next. Otherwise, we go to Step 6.

Step 6: Increase the transmission power weighting factor as $\mu = \mu + \Delta$. If $\mu > 1$, re-select parameters for the unequal error protection as well as the mode of modulation, and go to Step 3. If $\mu \le 1$, go to Step 4 and repeat the remaining steps.

The parameter Δ depends on the variation in the channel fading. The greater the variation in the channel fading, the greater the value of Δ; the lesser the variation in the channel fading, the smaller the value of Δ. In addition, the smaller the Δ variation, the larger is the power saving. Figure 2 shows the flow of the proposed power assignment mechanism. The length of MBOK codes for audio, video, and data packets are LC_a, LC_v, and LC_d, respectively, are 24, 12, 6, 2, 1. The channel coding rates of channel coding are 1/2, 2/3, and 3/4. The possible length of MBOK codes and channel coding for audio, video, and data packets are (24, 1/2), (24, 2/3), (24, 3/4), (12, 1/2), (12, 2/3), (12, 3/4), (6, 1/2), (6, 2/3), (6, 3/4), (2, 1/2), (2, 2/3), (2, 3/4), (1, 1/2), (1, 2/3), (1, 3/4). The initial power for audio, video, and data packets is 1/15 and the maximum power is 1.

3. Simulation Results

We have carried out a simulation to demonstrate the proper functionality of the proposed DS UWB wireless telemedicine system. In the simulation, we used K=6, 3/4 convolution code with soft decoding, and L=12 MBOK codes for the transmission of audio packets. For video packets, the K=6, 2/3 convolution code with soft decoding, and L=12 MBOK codes were used. For data packets, the K=6, 1/2 convolution code with soft decoding and L=24 MBOK codes were used. The system could perform channel estimation with a mean square error of 0.01. Moreover, we have assumed that the reference transmission power is μ =1 and the original transmission power weighting factor is Δ=1/15. There are four channel models (CMs) -CM1, CM2, CM3, and CM4- in the UWB system [29]. The target channel characteristics are described in the following. CM1 has a line-of-sight (LOS) signal similar to CM2, and CM3, while CM4 has a non-line-of-sight (NLOS) signal. The transmission distances are 0-4m, 0-4m, 4-10m, to be defined, and the root mean square (RMS) delays are 5-ns, 8-ns, 15-ns, and 25-ns for CM1, CM2, CM3, and CM4, respectively. In Figure 2, CM2 and the AWGN process with zero mean and variance σ_n^2 are employed. Figure 3 shows the transmission power weighting factors for data, audio, and video packets as a function of σ_n^2, the transmission power weighting for the data, video, and audio packets μ_d, μ_v and μ_a are denoted by the symbols (□), (O), and (Δ), respectively. The target SNRs to meet the required QoS for data, video, and audio bit streams are 10.74 dB, 12.09 dB and 16.10 dB, respectively. On the basis of CM2 and the specified QoS requirements for the audio, video, and data packets, Table I presents the transmission rates and the corresponding transmission power for $\Delta = 1/15$ in an unequal error protection DS UWB wireless telemedicine system with $\sigma_n^2 = -20\,\text{dB}$. Table II shows the obtainable transmission rates for various transmission power factors with $\Delta = 1/10$. From these two tables, we can observe that the use of the dynamic power assignment mechanism can maximize the system transmission rates or minimize the transmission power consumption as compared to an equal power DS UWB system**.** The decrease in the transmission power for unequal power assignment strategy in Table I and II is calculated as

$$\frac{(R_a + R_v + R_d) - (R_a\mu_a + R_v\mu_v + R_d\mu_d)}{R_a + R_v + R_d} \times 100\% \qquad (4)$$

where R_a, R_v, and R_d are the transmission rates for the audio, video, and data packets in the proposed DS UWB wireless telemedicine

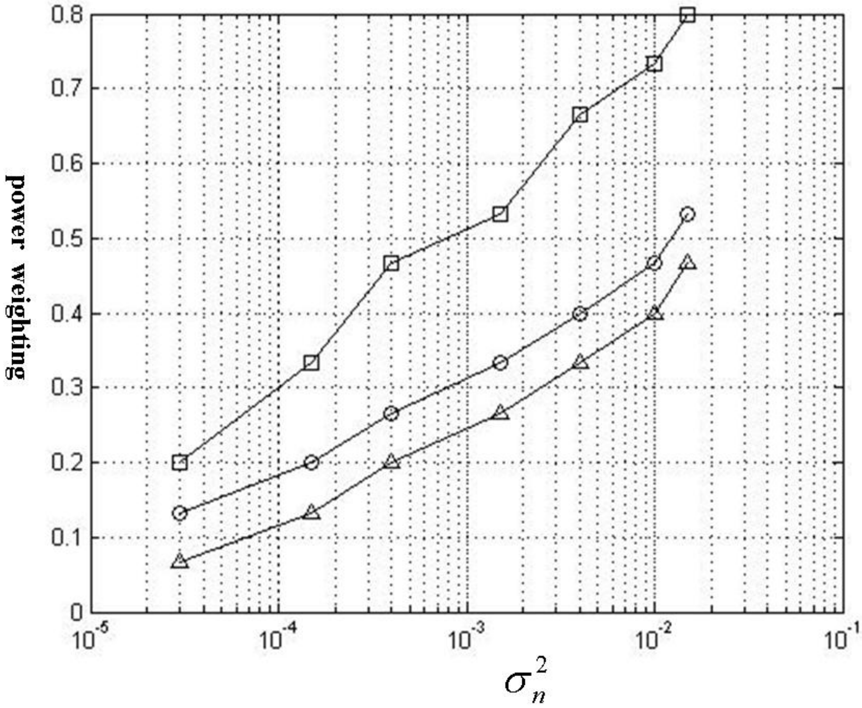

Figure 3. Transmission power weighting factors for data, audio, and video as a function of the AWGN with CM2. (power weighting factors for data, video, and audio packets are represented by □, O, and Δ, respectively).

Table I

Audio Signal 10^{-3}		**Video Signal** 10^{-4}		**Data Signal** 10^{-7}		**Descend Power (%)**
μ_a	R_a	μ_v	R_v	μ_d	R_d	
4/15	28Mbps	5/15	28Mbps	9/15	28 Mbps	60.01
5/15	55Mbps	6/15	55Mbps	9/15	28 Mbps	58.60
7/15	82Mbps	7/15	73Mbps	9/15	28 Mbps	51.29
1	165Mbps	1	146Mbps	9/15	28 Mbps	3.30

system under a reference transmission power, respectively; μ_a, μ_v, and μ_d are the transmission power weighting factors for the audio, video, and data packets, respectively. From the simulation results shown in Table I, it can be observed that when the power weighting factors are 7/15, 7/15, and 9/15 for the audio, video, and data packets, respectively, the obtainable corresponding transmission rates of 82-Mbps, 73-Mbps, and 28-Mbps can meet the differentiated QoS requirements of a wireless medical network. As compared to a DS UWB medical system with equal power transmission, our system can result in power saving up to

Table II

Audio Signal 10^{-3}		Video Signal 10^{-4}		Data Signal 10^{-7}		Descend Power (%)
μ_a	R_a	μ_v	R_v	μ_d	R_d	
3/10	28Mbps	4/10	28Mbps	6/10	28 Mbps	56.67
4/10	55Mbps	4/10	55Mbps	6/10	28 Mbps	55.94
5/10	82Mbps	5/10	73Mbps	6/10	28 Mbps	48.47
1	165Mbps	1	146Mbps	6/10	28 Mbps	3.30

51.29% power saving for $\Delta = 1/15$. From Table II, we can observe that the power saving is 48.47% for $\Delta = 1/10$. The smaller the Δ variation, the larger is the power saving. To further investigate the advantages of this system, we have undertaken a simulation by using the measured data. Figure 4 shows the received ECG signals. The mean square error of the original and the received ECG signals is 0.0063 in a DS UWB wireless medicine system with power assignment. Figure 5 shows the received EEG signals. The mean square error of the original and the received EEG signals is 0.0031 in a DS UWB wireless medicine system with power assignment. It is suitable for use in the field of medicine. Figure 6 shows the received and decoded G.729 audio signals in the DS UWB system with a power control mechanism. The mean square error of the original and the received audio signal is 0.003511. It is observed that the audio signal is very clear. Figure 7 shows the received and decoded JPEG2000 medical image. The peak signal-to-noise ratio (PSNR) of the JPEG-2000 medical images is 36.31dB. Figure 8 shows the received MPEG-4 CCD sensor video signals with an average SNR value of 33.1dB. From the above figures, we can observe that by using power assignment, not only can the system capacity can be increased but also the required QoS can also be realized. From the above discussion, we can observe that the proposed DS UWB transport architecture is a feasible platform for a wireless telemedicine system. In addition, such a system can achieve the maximum transmission rates, or the minimum transmission power consumption.

4 Conclusion

In this paper, power assignment schemes, unequal error protection strategies, and MBOK coding techniques are employed for medical messages with different characteristics to achieve the differentiated OoS requirements. In particular, for high transmission rate and real-time interactive audio/video signals, we use short MBOK codes, schemes with relatively less capable error protection schemes, and low transmission power. In contrast, long MBOK codes, more capable error protection schemes,

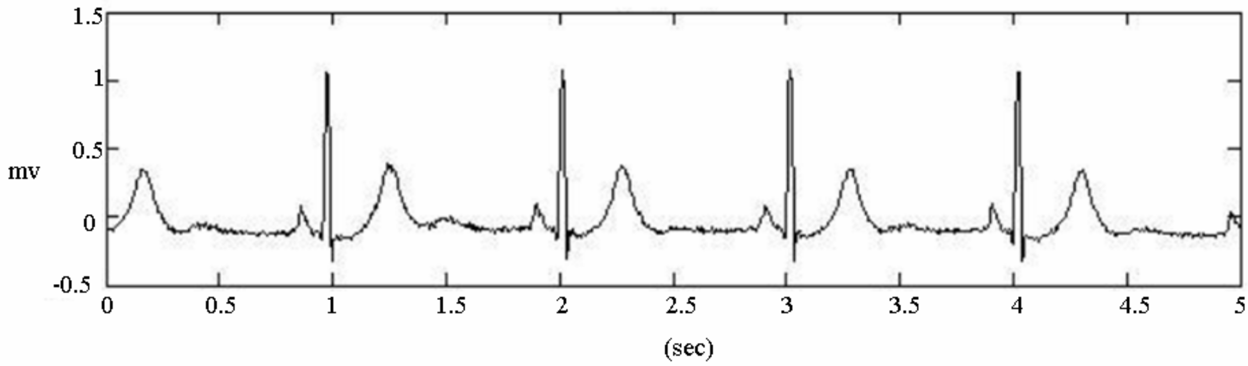

Figure 4 Received ECG signal in the DS UWB system with unequal error protection. (MSE= 0.0063)

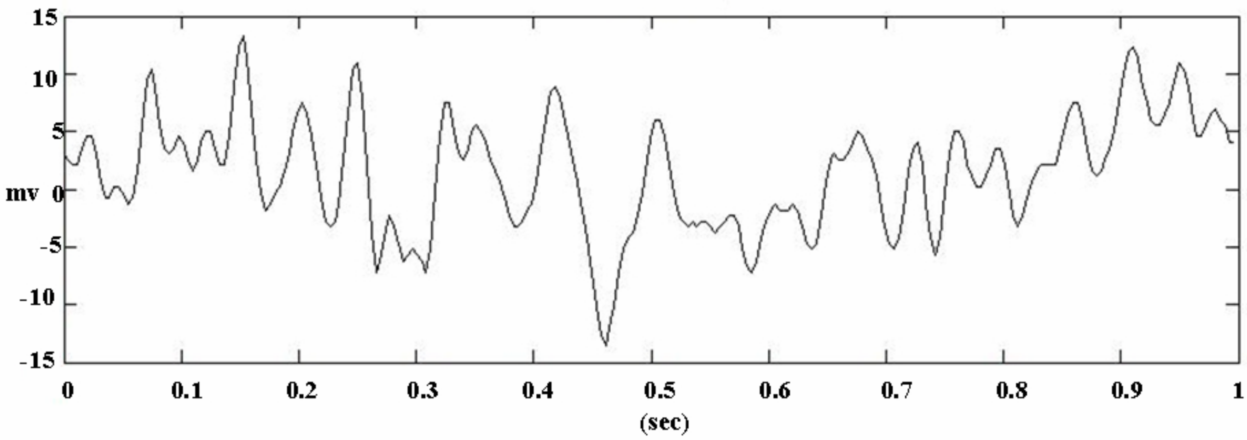

Figure 5 Received EEG signal in the DS UWB system with unequal error protection. (MSE=0.0031)

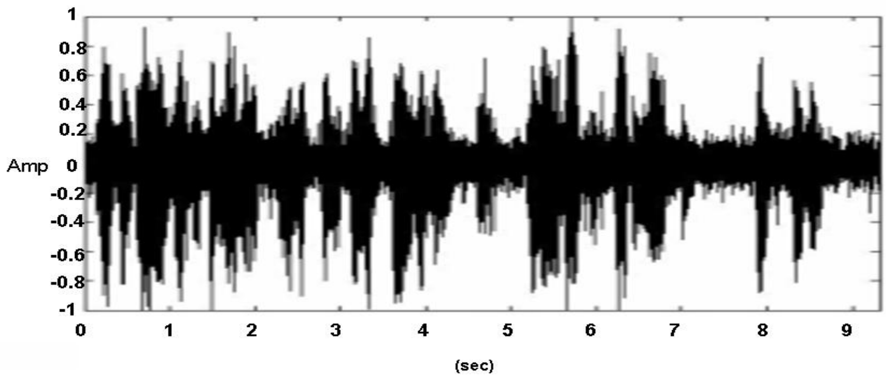

Figure 6 Received and decoded G.729 audio signals tested in the DS UWB system with unequal error protection.(MSE=0.003511)

Figure 7 Received image signals tested in the DS UWB wireless medical system with unequal error protection. (PSNR=36.31dB)

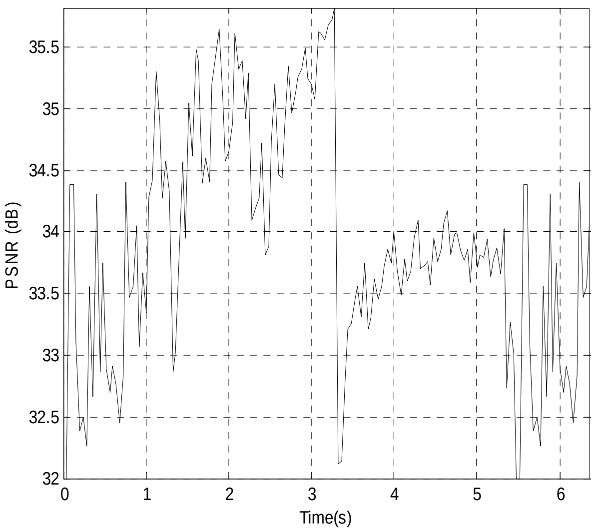

Figure 8 Received PSNR values of MPEG-4 CCD sensor video signals tested in the DS UWB wireless medical system with unequal error protection.

and high transmission power are provided for medical signals that necessitate a stringent BER. The simulation results have shown that the proposed DS UWB transport architecture can achieve the maximum transmission rates or the minimum transmission power consumption, and that it is a feasible platform for a wireless telemedicine system.

References

[1] B. Woodward, R. S. H. Istepanian, and C. I. Richards, "Design of a Telemedicine System Using a Mobile Telephone, "*IEEE Trans. Inf. Tech. Biomed.*, vol. 5, March, 2001, pp.13-15.

[2] S. G. Miaou and C. Y. Huang, "A Next-Generation Mobile Telemedicine Tested Based on 3G Cellular Standard, "*Proc. of IEEE Computer in Cardiology*, 2001, pp.683-686.

[3] C. S. Pattichis, E. Kyriacou, S. Voskarides, M. S. Pattichis, R. Istepanian, "Wireless telemedicine Systems: An Overview," *IEEE Antennas and Propagation Magazine*, vol.44,April, 2002, pp.143-153.

[4] Cabral J. E. and Kim Y., "Multimedia Systems for Telemedicine and Their Communications Requirement," *IEEE Commun. Magazine*, vol. 34, 1996, pp. 20-27.

[5] K. Hung and Y. T. Zhang,"Implementation of a WAP-Based telemedicine System for Patient Monitoring," *IEEE Trans. Inf. Tech. Biomed.*, vol. 7, June, 2003, pp.101-107.

[6] Y. Chu and A. Ganz, "A Mobile Teletruma System Using 3G Networks," *IEEE Trans. Inf. Tech. Biomed.*, vol. 8, December, 2004 pp.456-462.

[7] C. H. Calvador, M. P. Carrasco, M. A. G. Mingo, A. M. Carrero, J. M. Montes, L. S. Martin, M. A. Gavero, I. F. Lozano, and J. L. Monteagudo, "Airmed-Cardio: A GSM and Internet Services-based System for Out-of-Hospital Follow-up of cardiac patients," *IEEE Trans. Inf. Tech. Biomed.*, vol. 9, March, 2005, pp.73-85.

[8] L. Boquete, I. Bravo, R. Barea, J. M. R. Ascariz, and J. L. martin, "Practical Laboratory Project in Telemedicine: Supervision of Electrocardiograms by Mobile Telephony," *IEEE Trans. Education*, vol.48, May, 2005, pp.329-336.

[9] B. Fong, A.C.M. Fong, P.B. Rapajic, G.Y. Hong, "Mobile Telemedicine for Accident and Emergency Scenes in Tropical Regions," *WSEAS Trans. Comm.* Vol.2, 2003, pp.361-364.

[10] G. Mandellos, M. Koukias, G. Anastassopoulos, D. Lymperopoulos , "A new SCP-ECG module for telemedicine services," *WSEAS Trans.Computer*, Vol.3, 2004, pp.1258-1263.

[11] D. Kralj, and M. Stamenkovic, "Health Service and Environment Management System," *WSEAS International Conference on Mathematical Biology and Ecology 2006*, pp.20-24.

[12] Murakami H., Shimizu K., Yamamoto K., Hoshimiya T. N., Kondo K., "Telemedicine Using Mobile Satellite Communication," *IEEE Trans. Biomed. Eng.*, vol. 41, no. 5., May 1994, pp. 448-496.

[13] S. Pavlopoulos, E. Kyriacou, A. Berler, S. Dembeyiotis, and D. Koustouris, "A Novel Emergecy Telemedicine System Based on Wireless Communication---AMBULANCE, "*IEEE Trans. Inf. Tech. Biomed.*, vol. 2, December, 1998, pp.261-pp.267.

[14] Cypher D., Chevrollier N., Montavont N., and Golmie N., "Preailing over Wires in Healthcare Environments: Benefits and Challenges," *IEEE Communications Magazine*, 2006, pp.56-63.

[15] Y. H. Lin, I. C. Jan, P. C. I. Ko, Y. Y. Chen, J. M. Wong, and G. J. Jan, "A Wireless PDA-Based Physiological Monitoring System for Patient Transport," *IEEE Trans. Inf. Tech. Biomed.*, vol. 8, December, 2004, pp.439-.447.

[16] M. Fadlee, A. Rasid, and B. Woodward," Bluetooth Telemedicine Processor for Multichannel Biomedical Signal Transmission via Mobile Cellular Networks," *IEEE Trans. Inf. Tech. Biomed.*, vol. 9, March, 2005, pp.35-43.

[17] C. F. Lin, J. Y. Chen, R. H. Shiu, and S. H. Chang, "A Ka Band WCDMA-based LEO Transport Architecture in Mobile Telemedicine," *appear in Telemedicine in the 21st Century*, Nova Science Publishers, Inc, USA, 2008.(invited book chapter)

[18] C. F. Lin, W. T. Chang, H. W. Lee, and S. I. Hung, "Downlink Power Control in Multi-Code CDMA Mobile Medicine System," *Medical & Biological Engineering & Computing*, vol.44, 2006, pp.437-444.

[19] C. F. Lin, and K. T. Chang," A Power Assignment Mechanism in Ka Band OFDM-based Multi-satellites Mobile Telemedicine," *J. of Medical and Biological Engineering 2008*, pp.17-22.

[20] C.F. Lin , S. I. Hung , and I. H. Chiang," A 802.11n Wireless Medicine System," *Proc. of World Wireless Congress 2007*, pp.132~136.

[21] C. F. Lin, S. I. Hung , and K. T. Chang, "A 802.11n/Satellite 2 in 1 OFDM-based Transport Architecture Toward Seamless Mobile Telemedicine", *Proc. of World Wireless Congress*, 2008. pp.52~57.

[22] C. F. Lin and C. Y. Li, "A Power Control Scheme in DS UWB Wireless medical System, "*World Congress on Medical Physics and Biomedical Engineering*, 2006, pp. 3851~3855.

[23] C. F. Lin and C. Y. Li , "A DS UWB Wirelessmedical System, " *IEEE International Conference on Consumer Electronics*, 2007, pp.335-336.

[24] C. F. Lin and C. Y. Li, "A Power Assignment mechanism for DS UWB Wireless Telemedicine System with Unequal Error Protection," appear in *WSEAS Books(Proceedings of 12th WSEAS Int. Conf. on System*,2008, Greece), *invited paper*.

[25] C. F. Lin, C. H. Chung, Z. L. Chen, C. J. Song, and Z. X. Wang, "A Chaos-based Unequal Encryption Mechanism in Wireless Telemedicine with Error Decryption, " *WSEAS Transactions on Systems, Feb, 2008*, pp.49-55.

[26] FCC, "Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems," First Report and Order, ET Docket 98-153, FCC 02-8, adopted/released, Feb. 14/Apr. 22, 2002.

[27] M. Woo, N. Prabhu, and A. Ghafoor, "Dynamic resource allocation for multimedia services in mobile communication environments, " *IEEE J. Select. Areas Commun.*, Vol. 13, 1995, pp. 913-922.

[28] DS-UWB Physical Layer Submission to 802.15 Task Group 3a, *IEEE P802.15-04/0137r4*, January, 2005.

[29] Channel Modeling Sub-committee Report Final, *IEEE P802.15-02/490r1*, Febubary, 2003.