Performance Evaluation of Medical Image Transmission System using TH UWB-IR Technology

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***Abstract*—**In this paper, the transmission service for medical image is proposed via IEEE 802.15.4a on WPAN environment. Also, transmission and receiving performance of medical image using TH UWB-IR system is evaluated on indoor multi-path fading environment. On the results, the proposed scheme can solve the problem of interference from the medical equipment in same frequency band, and minimize the loss due to the indoor multi-path fading environment. Therefore, the transmission with low power usage is possible.

***Index Terms*—**Ultra Wideband, Time hopping, IEEE 802.15.4a, Medical image transmission.

I. INTRODUCTION

The conventional medical treatment service is possible only when and where doctor is located in the medical institute. Therefore, the limitation of time and space exists. Most of medical institute has limited number of doctor and fixed work time. In case of emergency, the status of patient can take a turn for the worse when relevant doctor is absent[1].

In modern society, the advance of medical equipment and technology enables the mobile type of equipments. These equipments only show limited information to the user, and transmit the limited diagnosis information to online medical personnel. Recently, via the emergence of high speed internet and wireless network environment, vast amount of multimedia data can be transmitted, and efficient diagnosis and prevention of disease is possible, which is customized for the status and need of the patient. By the miniaturization, digitalization, and making wireless, low power of diagnosis probes, the user can carry them all the time, and monitor the status of disease and health whenever and wherever possible. Also the emergency case can be expected and transmitted to near medical facility. Therefore, the high quality of medical service can be provided on the road.

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However, mobile medical equipment using wireless network has the interference problem with existing medical equipments, which use ISM spectrum, and larger battery power usage. High quality of transmission is not possible[2].

In this paper, the medical image transmission service via IEEE 802.15.4a specification on WPAN network is proposed. The proposed scheme can solve the problem of interference from the medical equipment on the same frequency band, and minimize the loss of medical image on indoor multi-path fading environment. Transmission with low power usage is possible.

II. TH UWB-IR SYSTEM

A. Frequency trend of IEEE 802.15.4a

Currently low rate WPAN area that the standardization is undergoing by IEEE 802.15.4a group enables the low cost/power, reliable data transmission and multiple device on network. This is expected to apply in much possible area[3].

15 channels are assigned from the physical class of IEEE 802.15.4a draft version.

Table 1 Units for Magnetic Properties

Channel Number	Center Frequency (MHz)	Band Width (3dB)	Mandatory/ Optional
1	3458	494	Optional
2	3952	494	Mandatory
3	4446	494	Optional
4	3952	1482	Optional
5	6337.5	507	Optional
6	7098	507	Optional
7	7605	507	Optional
8	8112	507	Mandatory
9	8619	507	Optional
10	9126	507	Optional
11	9633	507	Optional
12	10140	507	Optional
13	6591	1318.2	Optional
14	8112	1352	Optional
15	8961.75	1342.5	Optional

Frequency range of UWB technology is divided into low frequency range and high frequency range in 3.1~10.6 GHz as shown in Table 1. Channel 2 is used in low frequency range, and Channel 8 is employed in high frequency. Fig. 1 shows allocated frequency range in total UWB range.

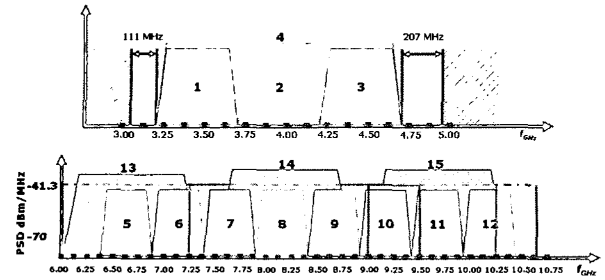


Fig. 1 The plan of IEEE 802.15.4a frequency assignment.

B. IEEE 802.15.4a TH UWB-IR System

Pulse $p(t)$, of TH UWB-IR has a period of T_p and energy, $E_p = \int_{-\infty}^{\infty} [p(t)]^2 dt$.

$$p(t) = t \exp\left(-2\pi\left[\frac{t}{t_n}\right]^2\right) \quad (1)$$

Where, t_n is parameter for deciding pulse width, and uses under nanosecond value. When the pulse of Gaussian mono cycle like equation (1) is introduced to receiver, input wave form, $p_{RX}(t)$, is expressed as equation(2)[4].

$$p_{RX}(t) = \left(1 - 4\pi\left[\frac{t}{t_n}\right]^2\right)\exp\left(-2\pi\left[\frac{t}{t_n}\right]^2\right) \quad (2)$$

Where, spectrum of signal and structure on time domain is determined by t_n.

In TH UWB-IR system, demodulation use the correlator, and normalized signal correlation function, $\gamma_p(\tau)$, is defined as follows[5].

$$\gamma_p(\tau) = \int_{-\infty}^{+\infty} p_{RX}(t) p_{RX}(t+\tau) dt = \left[1 - 4\pi\left[\frac{\tau}{t_n}\right]^2 + \frac{4\pi^2}{3}\left[\frac{\tau}{t_n}\right]^4\right]\exp\left(-\pi\left[\frac{\tau}{t_n}\right]^2\right) \quad (3)$$

Transmission signal of UWB-IR system is shown in Fig. 2, and transmission signal via considering the multiple accesses is shown in Fig. 3.

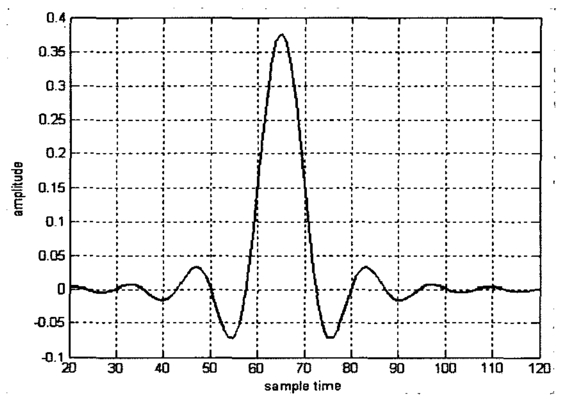


Fig. 2 UWB-IR transmission signal.

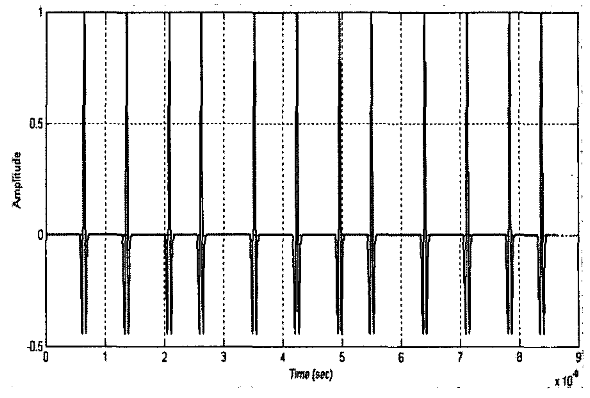


Fig. 3 TH UWB-IR transmission signal (TH code word=4)

C. Model of indoor multi-path channel

UWB system directly transmit via pulse row, and received signal is classified depending on value of δ. Therefore, in case that time delay δ, which is received via indirect path, the signal detection performance is effected at correlator. Time delay between direct wave and indirect wave is calculated using following equation, where c stands for the velocity of wave.

$$\Delta t = (R - D)/c \quad (4)$$

Fig. 4 shows the effect of direct wave due to the path delay time.

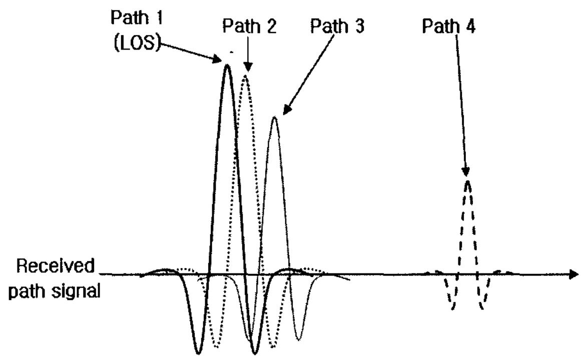


Fig. 4 The effect of between direct wave and path wave due to the path delay time.

In case of path 4 in Fig. 4, indirect pulse, which has larger time delay, Δt, than the width of direct pulse, has no effect on the received direct pulse wave. However, path 2 and 3, which has smaller time delay, Δt, than width of direct pulse, can generate critical interference in demodulation of reception signal.

In this study, to model the channel generated from the multi-path delay, the multi-path parameter of interior office environment, which is recommended by ITU-R M.1225, is applied to analyze the system performance [6]. In Table 2, the parameters suggested by ITU-R M.1225 are shown, Suggested wireless channel environment consists of channel A, which has relatively smaller delay spread, and channel B, which has intermediate delay spread.

Table 2 Parameter of TDL in indoor office environment.

Tap	ITU-R M.1225		Modeling Parameter	
	Channel A	Channel B	Channel A	Channel B
	Delay (ns)		Tap Weight	
1	0	0	0.6172	0.5784
2	50	100	0.3093	0.2525
3	110	200	0.0617	0.1102

III. PERFORMANCE ANALYSIS OF SYSTEM

In Table 3, the simulation parameters for medical picture transmission system are shown via TH UWB-IR system

Table 3 Simulation Parameters.

Simulation parameter	
Medical Image	Gray scale bitmap Image (128×128)
Medical Information Transmission System	TH UWB-IR
Channel Environments	AWGN+ 3-ray multi-path fading
TH UWB-IR Parameter	
Frequency Band	8.112 GHz (center frequency) 507 MHz (3dB bandwidth)
Data rate	1 Mbps
Modulation index	2 (binary PPM)

Fig. 5 shows BER performance graph for 1Mbps data transmission on multi-path fading channel environment in TH UWB-IR medical picture transmission system.

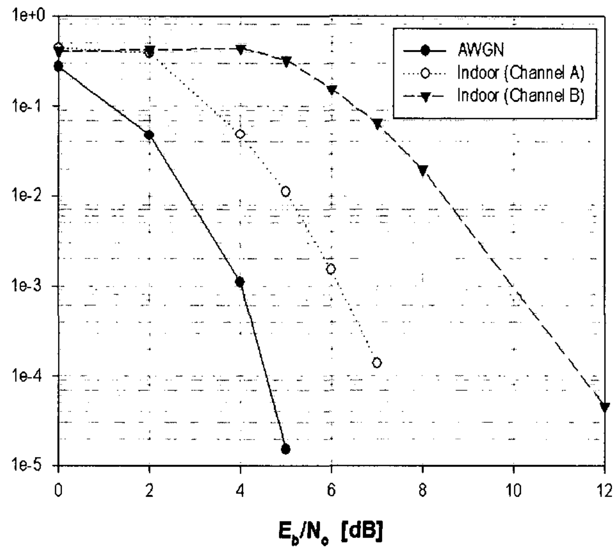


Fig. 5 BER performance of TH UWB-IR system in multi-path fading environment.

In case of channel B, which has larger delay spread than channel A, 5dB of SNR performance difference is achieved to meet 10^{-3} BER like channel A in interior office environment, Fig. 6 shows the comparison on PSNR of received picture for multi-path fading channel environment in TH UWB-IR medical picture transmission system.

Quality of picture should be evaluated by person, but for the objective evaluation criteria S/N ratio is frequently used. This is different from the conventional transmission S/N ratio. Following equation is the definition of PSNR. Numerator terms represent the maximum 255 signal of original image in case of 8bit/pixel picture. Denominator terms represent the noise, which use the difference between original and reconstructed image.

$$PSNR\ (a,b) = 10 \log_{10}\left[\frac{255^2}{\frac{1}{N \times M}\sum_{x=0}^{N-1}\sum_{y=0}^{M-1}[a(x,y)-b(x,y)]^2}\right] \quad (5)$$

In above equation, a is original picture, and b is reconstructed picture. (x, y) is combination of pixel.

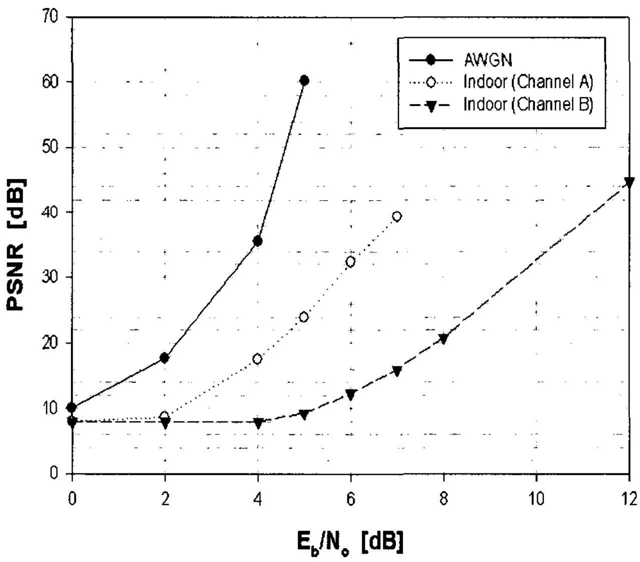


Fig. 6 Variation of PSNR Medical Image Trans- mission System according to channel environment.

In case of image, over 30dB of PSNR is supposed for no deterioration. In Fig. 6, reception SNR is about 6dB for 30dB of PSNR. However, for channel B, higher SNR (over 11dB) is required. Fig 7 visually shows the performances of received picture for varying status of multi-path fading channel in TH UWB-IR medical image transmission system.

In case of channel A, visible analysis of medical picture is possible for over 4dB of SNR. In case of channel B, visible analysis is possible for over 8dB of SNR. Therefore, to transmit medical picture, which requires minimum distortion, error correction technique should be applied for low power consumption and high quality transmission.

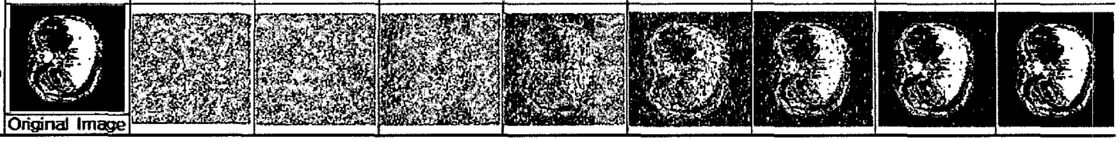
	SNR	0	2	4	5	6	7	8	12
Indoor Office Env. (Channel A)	PSNR	7.9686	8.6408	17.4943	23.9237	32.3637	39.4186		
	BER	0.4383	0.3868	0.0486	0.0111	0.0015	1.3725e-004		
	Original Image								
Indoor Office Env. (Channel B)	PSNR	5.4055	5.4474	7.9872	9.2685	12.2935	15.8998	20.7995	44.7138
	BER	0.4882	0.4734	0.4393	0.3278	0.1565	0.0650	0.0199	4.5748e-005
	Original Image								

Fig. 7 Comparison of received image to TH UWB-IR Medical Image Transmission System in multi-path fading environment.

IV. CONCLUSION

In this paper, the medical picture transmission service using IEEE 802.15.4a specification for low-rate transmission on WPAN environment is suggested. Also, the performance analysis on transmission and reception of medical picture using TH UWB-IR of IEEE 802.15.4a on interior multi-path fading environment is conducted and quality of received video picture is analyzed. In case of channel A, which has smaller delay spread, under SNR=10dB about 10^{-4} BER is shown. However, in case of channel B, due to the larger delay spread, ISI is increased, and the deterioration of performance is severe than channel A.

Therefore, to transmit the medical picture via TH UWB-IR system, suppressing technique for multi-path interference should be studied on channel B-like environment. The suggested way can solve the problem of interference from the medical equipment in same work space, and minimize the loss of medical picture on interior multi-path fading environment. Therefore, the transmission with low power usage is possible.

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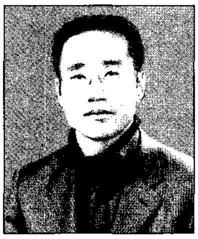

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