World Academy of Science, Engineering and Technology
International Journal of Information and Communication Engineering
Vol:1, No:12, 2007

Impact of Metallic Furniture on UWB Channel Statistical Characteristics by BER

Yu-Shuai Chen , Chien-Ching Chiu , Chung-Hsin Huang, and Chien-Hung Chen

Abstract**—**The bit error rate (BER) performance for ultra-wide band (UWB) indoor communication with impact of metallic furniture is investigated. The impulse responses of different indoor environments for any transmitter and receiver location are computed by shooting and bouncing ray/image and inverse Fourier transform techniques. By using the impulse responses of these multipath channels, the BER performance for binary pulse amplitude modulation (BPAM) impulse radio UWB communication system are calculated. Numerical results have shown that the multi-path effect by the metallic cabinets is an important factor for BER performance. Also the outage probability for the UWB multipath environment with metallic cabinets is more serious (about 18%) than with wooden cabinets. Finally, it is worth noting that in these cases the present work provides not only comparative information but also quantitative information on the performance reduction.

Keywords**—**UWB, multipath, outage probability.

I. INTRODUCTION

WHEN the Federal Communications Commission (FCC) agreed in February 2002 to allocate 7500 MHz to spectrum for unlicensed use of ultra-wideband (UWB) devices for communications in the 3.1 – 10.6 GHz frequency band [1], the UWB technology has been the subject of extensive research in recent years due to its potential applications and unique capabilities. Low transmission power and short distance operation with UWB results in an extremely low transmitted power spectral density, which insures that impulse radio do not interfere with narrow-band radio systems operating in dedicated bands.

There are two basic methods to produce UWB signals. One way is to make use of OFDM in producing a GHz signal in frequency spectrum, the other way is impulse radio (IR) technology that directly produces a pulse, and this pulse's duration is only in the level of nanosecond [2-3]. Here, we motivate the suitability of IR UWB system that it offers many potential advantages, such as high resolution in multipath reducing fading margins in link budget analysis, allowing for low transmit powers and low complexity.

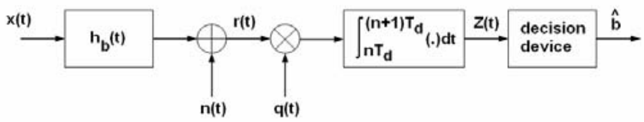

Fig. 1 Block diagram of the simulated communication system

Chien-Ching Chiu is with the Electrical Engineering Department, Tamkang University Tamsui, Taipei, R.O.C. (phone: 886-2621-5656 #2737; fax: 886-2620-9814; e-mail: chiu@ee.tku.edu.tw).

Yu-Shuai Chen is with the Electrical Engineering Department, Tamkang University Tamsui, Taipei, R.O.C. (e-mail: kenny71526@yahoo.com.tw).

Chung-Hsin Huang is with the Electrical Engineering Department, Tamkang University Tamsui, Taipei, R.O.C. (e-mail: 691350010@s91.tku.edu.tw).

Chien-Hung Chen is with the Electrical Engineering Department, Tamkang University Tamsui, Taipei, R.O.C. (e-mail: g8350039@tkgis.tku.edu.tw).

All wireless systems must be able to deal with the challenges of operating over a multipath propagation channel, where objects in the environment can cause multiple reflections to arrive at the receiver. BER degradation is caused by intersymbol interference (ISI) due to a multipath propagation made up of radio wave reflections by walls, floor, ceiling, laboratory fixtures. Generally, 100Mbps transmission was actually confirmed to be available for an allowable BER of 10^{-5} [4-6].

In this paper, we use ray tracing techniques and inverse Fourier transform to compute the impulse for UWB indoor communication, and the BER performance for binary pulse amplitude modulation (BPAM) impulse radio (IR) UWB system with impact of metallic furniture is investigated. Channel modeling and system description is presented in section II. Section III shows the numerical results. Finally, some conclusions draw in section IV.

II. CHANNEL MODELING AND SYSTEM DESCRIPTION

A. Calculation of the Channel Characteristics

The equation used to model the multipath radio channel is a linear filter with an equivalent baseband impulse response given by

$$h_b(t) = \sum_{l=1}^{N} \alpha_l e^{j\beta_l} \delta(t - \tau_l) \tag{1}$$

Where l is the path index, α_l is the path attenuation, β_l is the phase shift and τ_l is the time delay of the l th path. $\delta(.)$ is the Dirac delta function [7]. The goal of channel modeling is to determine the α_l , β_l and τ_l for any transmitter-receiver location in the station. The impulse response function of the station for any transmitter-receiver location is computed as the following two steps: frequency responses for sinusoid waves by SBR/Image techniques and inverse fast Fourier transform (IFFT) and Hermitian processing [8].

The SBR/Image method can deal with high frequency radio wave propagation in the complex indoor environments. It conceptually assumes that many triangular ray tubes are shot from the transmitting antenna (Tx) and each ray tube bouncing and penetrating in the environments is traced in indoor multi-path channel. The first order wedge diffraction is included, and the diffracted rays are attributed to corresponding image. Depolarization yielded by multiple reflections on walls and floors is also taken into account in our simulations.

The frequency responses are transformed to the time domain by using inverse Fourier transform with Hermitian signal processing. Using Hermitian Processing, the pass-band signal is obtained with zero padding from the lowest frequency down to DC (direct current), taking the conjugate of the signal, and reflecting it to the negative frequencies. The result is then transformed to the time domain using IFFT. Since the signal spectrum is symmetric around DC. The resulting doubled-side spectrum corresponds to a real signal in time domain.

B. System Block Diagram

The transmitted UWB pulse stream is [9]:

$$x(t) = \sqrt{E_{tx}} \sum_{n=0}^{1} p(t - T_s - nT_d) d_n \tag{2}$$

Where T_p is the pulse duration and T_d is the one pulse per frame of frame duration ($T_d >> T_p$), T_s is the inter pulse separation time ($T_s = \frac{1}{2} T_d$). In Fig. 1, the second derivative Gaussian waveform $p(t)$ has ultra-short duration T_p at the nanosecond scale, and average power limits set by the FCC in the U.S. for indoor UWB devices. Binary PAM symbols $d_n \in \{\pm 1\}$ being independent identically distributed (i.i.d.) and average transmit energy symbol E_{tx}.

The diagram of transmitted waveform is shown in Fig. 2. After propagating through channel, the received signal takes on the general form

$$r(t) = [x(t) \otimes h_b(t)] + n(t) \tag{3}$$

$q(t)$ is the correlation of the reference signal

$$q(t) = \sum_{n=0}^{1} p(t - \tau_1 - T_s - nT_d) \tag{4}$$

The output of the n th sub-band correlator is

$$Z(t) = \int_{nT_d}^{(n+1)T_d} \left\{ [\sqrt{E_{tx}} \sum_{n=0}^{1} p(t - T_s - nT_d) d_n] \otimes h_b(t) \right\} x_b(t) \cdot q(t) dt + \int_{nT_d}^{(n+1)T_d} n(t) q(t) dt$$
$$= V(t) + \eta(t) \tag{5}$$

The variance of the output noise η is $\sigma^2 = \frac{N_o}{2} E_{tx}$.

Finally, the BER for BPAM IR UWB system can be expressed as

$$BER = \sum_{n=1}^{\infty} P(\bar{a}_n) \cdot \frac{1}{2} erfc \left[\frac{V(t = (n+1)T_d)}{\sqrt{2}\sigma} \cdot (d_n) \right] \tag{6}$$

III. Numerical Results

Since the dielectric permittivity and the loss tangent of the materials changes with frequency, the different values of dielectric constant and loss tangent of materials for different frequency are carefully considered in channel calculation [10]. The dielectric constant and loss tangent of wood are shown in Table I.

Fig. 2 is the Microwave laboratory in Tamkang University and this laboratory has dimensions of 9.2m (Length) x 10m (Width) x 3m (Height). The laboratory with L-shape metallic cabinet or L-shape wooden cabinet is considered in the simulation. The transmitting and receiving antennas are both short dipoles and vertically polarized. The transmitting antenna Tx (250, 400, 120) cm is located on the center of the wood table in the Microwave laboratory. 1250 different locations of receiver antenna with uniformly distributed in the laboratory are chosen for simulations. Meanwhile the receiver antenna at Rx1 (400, 500, 75) cm and Rx2 (650, 525, 75) cm are also plotted in Fig. 1 for the further discuss. The maximum number of bounces setting beforehand is four, and the convergence is confirmed. Several simulation traces and the results of data analysis of individual simulation in this collection are presented in.

Fig. 3 shows the bit error rate (BER) versus Eb/No for receivers at Rx1 and Rx2. For a BER $=10^{-5}$ and the receiver antenna at Rx2 located behind of the cabinet, the Eb/No value for metallic cabinet is larger than that for the wooden cabinet about 6dB, due to the fact that radiowave can pass through the wooden cabinet and is blocked by the metallic cabinet. Furthermore, for the wooden cabinet, the Eb/No value at Rx2 is larger than that at Rx1 about 4dB, due to Rx1 has a line-of-signal(LOS) wave and Rx2 has only non-line-of-signal (NLOS) waves. Finally, the performance at Rx2 located in back of the metallic cabinet is catastrophically bad while comparing with the Rx1.

Fig. 4 shows the outage probability versus Eb/No. The outage probabilities depicted in Fig. 4 for a BER $<10^{-5}$ and Eb/No= 20dB are about 27.4% and 9.3 % for the metallic and the wooden cabinets respectively. It is clear that the BER performance for the wooden cabinet is better.

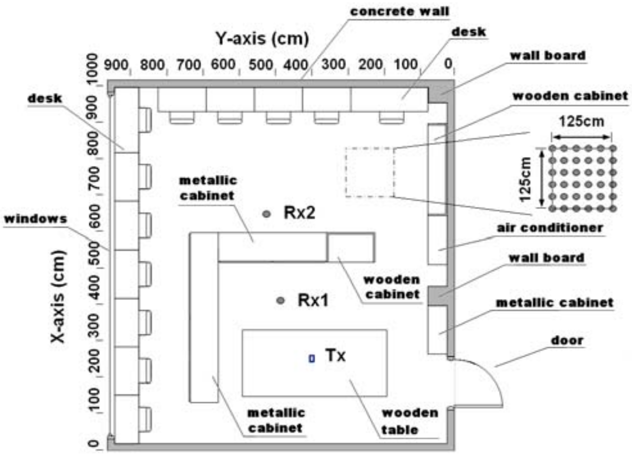

Fig. 2 Top view of the Microwave laboratory in Tamkang University and this laboratory has dimensions of 9.2m (Length) x 10m (Width) x 3m (Height). The transmitter is located at Tx (250, 400, 120) cm, the receiver are located at Rx1 (400, 500, 75)cm and Rx2 (650, 525, 75)cm

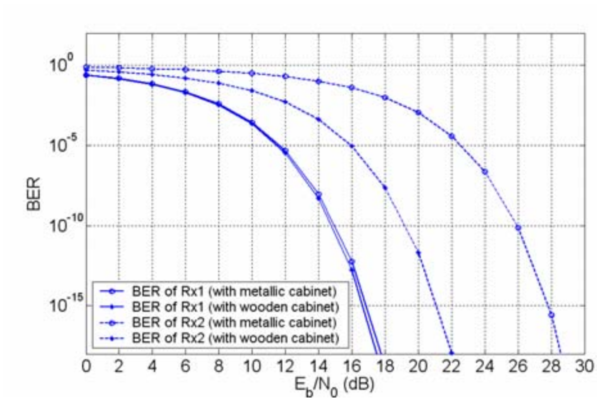

Fig. 3 BER performance for the metallic and wooden cabinets

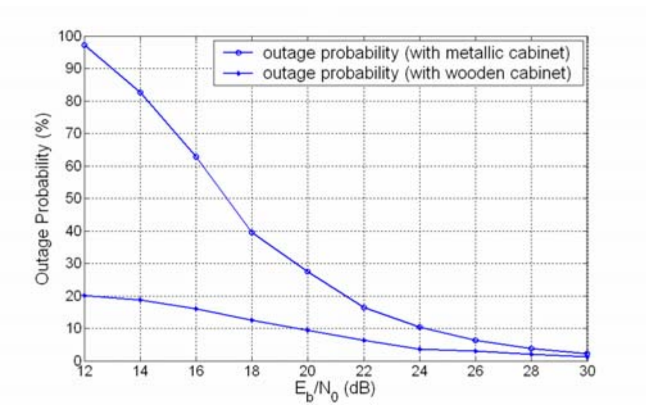

Fig. 4 Outage probability versus Eb/No for a system with 1250 receivers

TABLE I
THE DIELECTRIC CONSTANT AND LOSS TANGENT OF CONCRETE WALL

Wood		
Frequency (GHz)	Dielectric Constant	Loss Tangent
3.0	2.17	4.61E-01
3.5	2.15	4.41E-01
4.0	2.14	4.25E-01
4.5	2.13	4.13E-01
5.0	2.12	4.03E-01
5.5	2.10	3.94E-01
6.0	2.10	3.87E-01
6.5	2.09	3.81E-01
7.0	2.09	3.75E-01
7.5	2.08	3.70E-01
8.0	2.08	3.66E-01
8.5	2.08	3.62E-01
9.0	2.07	3.56E-01
9.5	2.07	3.53E-01
10.0	2.07	3.49-01

IV. CONCLUSIONS

The BER performance for BPAM UWB indoor communication with metallic cabinet and with wooden cabinet has been investigated. By using the impulse response of the multipath channel, the BER for high-speed UWB indoor communication has been calculated, the impact of metallic cabinet to indoor multi-path is presented and the channel statistical characteristics are analyzed. Moreover, the frequency dependence of materials utilized in the structure on the indoor channel is accounted for in the channel simulations. Numerical results show that the outage probability for the UWB multi-path environment with metallic cabinets is more serious than with wooden cabinet. This is due to the fact that the multi-path effect is severe when metallic cabinets exist in the room. Finally, it is worth noting that in these cases the present work provides not only comparative information but also quantitative information on the performance reduction.

REFERENCES

[1] "First report and order, revision of part 15 of the communication's rules regarding ultra-wideband transmission systems," *FCC, ET Docket*, pp. 98 – 153, Feb. 14, 2002.

[2] Siwiak, K.; Withington, P.; Phelan, S., "Ultra-wide band radio: the emergence of an important new technology," *IEEE VTS 53rd .Vehicular Technology Conference, 2001. VTC 2001 Spring.* Vol. 2, pp. 1169 – 1172, May 2001.C. C. Chiu and C. P. Huang, "Inverse scattering of dielectric cylinders buried in a half space," *Microwave and Optical Technology Letters*, Vol. 13, pp. 96-99, Oct. 1996.

[3] Siwiak, K., "Ultra-wide band radio: introducing a new technology," *IEEE VTS 53rd .Vehicular Technology Conference, 2001. VTC 2001 Spring.* Vol. 2, pp. 1088 - 1093, May 2001

[4] Mielczarek, B.; Wessman, M.O.; Svensson, A.., "Performance of coherent UWB Rake receivers with channel estimators," *IEEE 58th Vehicular Technology Conference,* pp. 1880 - 1884, Oct. 2003.

[5] Hamalainen, M.; Iinatti, J., "Analysis of Interference on DS-UWB System in AWGN Channel," *2005 IEEE International Conference on Ultra-Wideband*, pp. 719 - 723, 2005.

[6] Kandukuri, S.; Boyd, S., "Optimal power control in interference-limited fading wireless channels with outage-probability specifications," *IEEE Transactions on Wireless Communications,* pp. 46 - 55, 2002.

[7] Saleh AAM, Valenzuela RA., "A statistical model for indoor multipath propagation," *IEEE Journal on Selected Areas in Communication ,* Vol. 5, pp. 128 – 137, 1987.

[8] C. H. Chen, C. L. Liu, C. C. Chiu and T. M. Hu, "Ultra-Wide Band Channel Calculation by SBR/Image Techniques for Indoor Communication," Journal of Electromagnetic Waves and Applications Vol. 20, No. 1, pp. 2169-2179, 2006.

[9] Zhi Tian; Giannakis, G.B., "BER sensitivity to mistiming in ultra-wideband impulse Radios-part I: nonrandom channels," *IEEE Transactions on Signal Processing,* pp. 1550 - 1560, Apr 2005.

[10] Gargin, D.J., "A fast and reliable acquisition scheme for detecting ultra wide-band impulse radio signals in the presence of multi-path and multiple access interference" *2004 International Workshop on Ultra Wideband Systems,* pp. 106 - 110, May 2004.