BER PERFORMANCE SIMULATION IN LOS ENVIRONMENT FOR FIXED BROADBAND WIRELESS ACCESS SYSTEM

Tang Min Keen , Tharek Abdul Rahman
Wireless Communication Centre, Faculty of Electrical Engineering,
Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

Keywords: BER performance, Channel modelling, Fixed Broadband Wireless Access

Abstract: This paper presents a straightforward bit error rate (BER) performance simulation methodology that can be readily used for FBWA system with environment effects being taken into consideration. This work begins with physical layer modelling of a current market available fixed broadband wireless access (FBWA) system.Then, with the eight modelled line of sight (LOS) channels obtained from prediction and measurement, BER performance of the system in the related environment is simulated. The FBWA system is a high performance and high-speed wireless Ethernet bridge terminal, which operates in the Unlicensed National Information Infrastructure (UNII) band of 5.8 GHz with orthogonal frequency division multiplexing (OFDM) wireless transmission. Tests and verifications have been carried out in the simulation tools in order to ensure the modelled system is conforming the standard and specifications of the actual system. With the physical layer system template and the channel models that represent the real environment, the BER computations are obtained

1 INTRODUCTION

Wireless local area networks (WLAN) supporting broadband multimedia communication are being developed and standardized around the world. IEEE 802.11a is one of the standards that provides an internationally accepted standard defining independent PHY and MAC layers at UNII frequency band of 5 GHz. As mandated by Federal Communications Commission (FCC), the IEEE 802.11a is applying to lower band (5.15-5.25 GHz) for indoor applications, middle band (5.25-5.35GHz) for indoor or outdoor applications and upper band (5.725-5.825 GHz) for outdoor applications. Here, the modelled FBWA system operates in the upper band that is designed for outdoor point to point application. It meets the standard requirements for IEEE 802.11a.

The terminology, quality targets and methodologies to be used in the planning of fixed wireless systems are defined in F-series of the radio communication sector of the International Telecommunication Union (ITU-R) recommendations. BER is one of the quality parameters, which is used to define the performance and range of radio systems. (Clark, 2000) Hence, to know the performance range of the system used, the system is modeled and simulated using a powerful simulation software tool.

This paper is organized as follows: Firstly, a brief description and results of transmitter tests that include spectrum mask, error vector magnitude and relative constellation error test are presented. This is followed by receiver sensitivity level, adjacent and alternate channel rejection test to confirm the modelled receiver with related standard and specifications. Then, a short summary about the eight LOS channel models is explained in Section IV. Finally, the results of physical layer software simulation are given in the form of bit error rate (BER) versus energy per bit to noise ratio (E_b/N_0) and discussed before this paper is concluded.

2 TRANSMITTER TEST

According to FCC regulations as stated in (IEEE 802.11a, 1999) section 17.3.9.1, the maximum allowable output power is 40 mW (50 mW/MHz) with up to 6dBi antenna gain. Though the maximum power level is depending on the standard, the

Min Keen T. and Abdul Rahman T. (2004).
BER PERFORMANCE SIMULATION IN LOS ENVIRONMENT FOR FIXED BROADBAND WIRELESS ACCESS SYSTEM.
In *Proceedings of the First International Conference on E-Business and Telecommunication Networks*, pages 166-171
DOI: 10.5220/0001392701660171

software of the system will determine the actual power. The system has different actual transmit power permitted for each channel according to the modulation scheme. Yet, the defined value is lower than the maximum allowable values by the relevant standard. To achieve higher radiated power that is allowed by the standard, a high gain directional antenna will be used. In the software tool, the maximum transmit power for the system is set.

In section 17.3.9.2, the transmit spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, -20 dBr at 11 MHz frequency offset, -28 dBr at 20 MHz frequency offset and –40dBr at 30 MHz frequency offset and above. Here, the nine channels that available in this system are measured. It is found that all the transmit signal falls within the allowable spectral mask shown in the Figure 1.

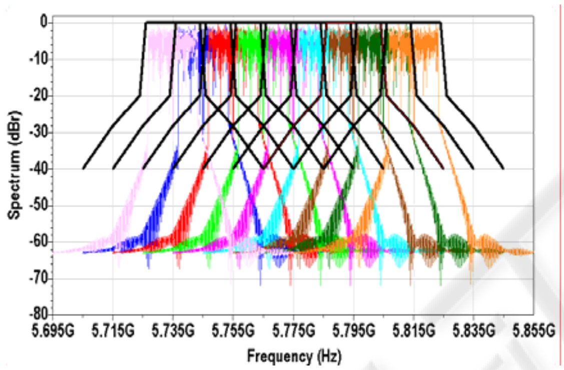

Figure 1: Transmit RF Spectrum

The error vector between the vector representing the transmitted signal and the vector representing the error-free modulated signal defines modulation accuracy. The magnitude of the error vector is called EVM. The purpose of this test is to verify that the root mean square (rms) EVM measured on the specific part of the burst meets the conformance requirement. EVM and relative constellation error measurements here are based on (IEEE 802.11a, 1999) section 17.3.9.6 and section 17.3.9.7. The test for every sub carrier is performed over 20 frames and the rms average is taken. Simulation results show that all the EVM, averaged over sub-carriers, OFDM frames and packets are less than 0.003%, and the constellation are approximately –88 dB which is much smaller than the specification requirements.

3 RECEIVER TEST

The receiver performance requirements (IEEE 802.11a, 1999) are listed in Table 1. Firstly, the packet error rate (PER) for rate-dependant input levels in the table are tested less than 10% at a physical sublayer service data units (PSDU) length of 1000 bytes The minimum input levels are measured at antenna connector with noise factor of 10 dB and 5 dB implementation margins. The simulation result is displayed in Figure 2. It shows that at PER 10^{-1} (10%), the received signal levels is lower than the minimum sensitivity allowed.

Secondly, the adjacent channel rejection is tested by setting the desired signal's strength 3dB above the rate-dependent sensitivity specified in Table 1 and raising the power of the interfering signal until 10% PER is caused for PSDU length of 1000 bytes. The power difference between the interfering and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel is also a conformant OFDM signal, unsynchronized with the signal in the channel under test.

Thirdly, the same setting applies for the non-adjacent channel rejection. The non-adjacent channel rejection is also called alternate channel rejection where the interfering signal is 40 MHz from the channel under test. Figure 3 and 4 show the power versus spectrum for data rate at 54 Mbps with interference signal 10dB higher than the actual signal for adjacent rejection channel and interference signal 15dB higher than the actual signal for alternate rejection channel rejection. The simulation results for adjacent and alternate rejection tests are shown in Figure 5 and 6. At PER equals to 10^{-1} (10%), all the adjacent and alternate channel rejection for the eight data rate are higher than the standard values and so the system fulfils the requirements.

Table 1: Receiver performance requirements

Data Rate (Mbits/s)	Minimum sensitivity (dBm)	Adjacent channel rejection (dB)	Alternate channel rejection (dB)
6	-82	16	32
9	-81	15	31
12	-79	13	29
18	-77	11	27
24	-74	8	24
36	-70	4	20
48	-66	0	16
54	-65	-1	15

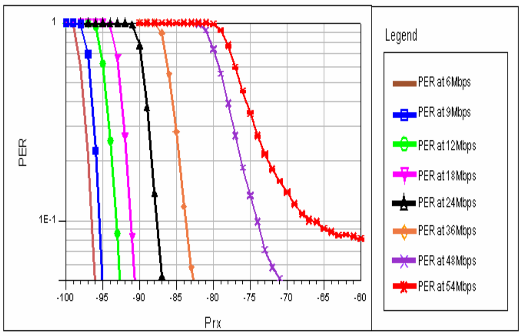

Figure 2: Receiver Sensitivity

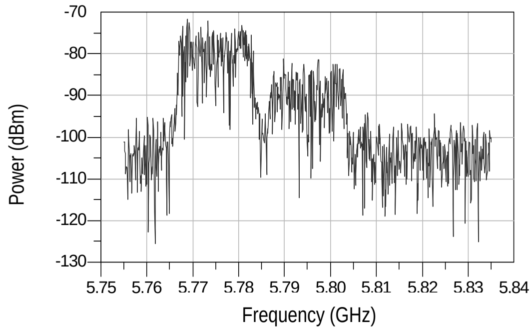

Figure 3: Adjacent Channel Rejection

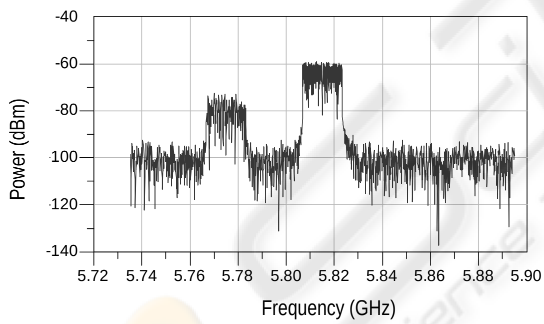

Figure 4: Alternate Channel Rejection

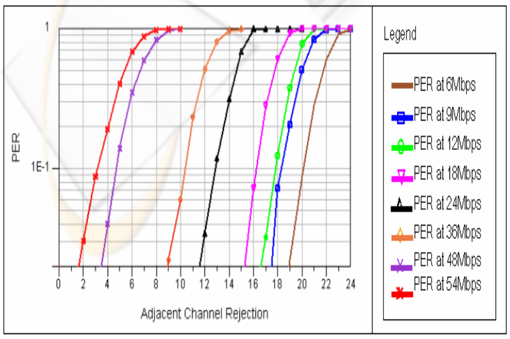

Figure 5: Adjacent Channel Rejection Test

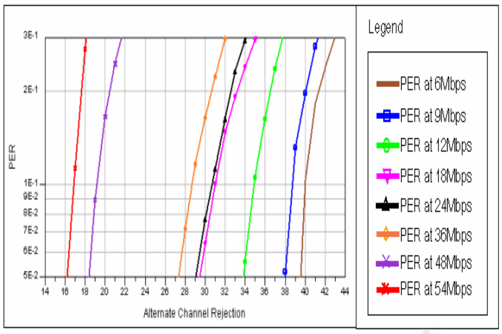

Figure 6: Alternate Channel Rejection Test

4 CHANNEL MODELS

The channel models are obtained from a 3D Vertical Plane Launch (VPL) ray tracing technique (Liang and Bertoni. 1998) that incorporates site specific environmental data in a newly constructed hostel in Universiti Teknologi Malaysia (UTM) for 5.8 GHz carrier frequency. Transmit site is at Wireless Communication Centre (WCC). The receiver sites consist of 8 LOS locations in a two u-shaped hostel's buildings, which are located around 50 meters lower than WCC. The terrain between WCC and the hostel is a small oil palm plantation. Hence, the site overlooked a terrain of light rolling hills with moderate tree densities. From the highest floor of WCC, we can see these buildings and the oil palm plantation. The distances for these links are ranged from 416 to 564 meter. Figure 7 and 8 show the photo of WCC and the photo of the hostels that is captured from WCC.

With building, terrain, and antenna databases, and also transmitter and receiver locations databases, the 8 channel models are obtained from the propagation prediction. However, this model excluded the vegetation effects that appeared in the fresnel zone clearance in the real site environment. Modification is needed on predicted channel models to take account of the obstruction loss. Path loss field measurement has been conducted using the FBWA system. To assure that propagation channel is stationary in time, the measured data is averaged over 30 instantaneously sampled values in 15 minutes. The deviation within free space loss and measurement loss is used to consider the obstruction loss of vegetation in fresnel zone. After adding relatively the computed obstruction loss into each component of the ray of the links, the complete sets of output magnitudes are ready for BER performance. The parameters of the eight channels are listed in the Table 2. A more detail explanation of channel modeling can be found in (Tang and Tharek, 2004)

Table 2: Channel Models

Channel Num.	Distance (meter)	Tap Num.	Delay (ns)	Average Relative Power (dB)	RMS Delay Spread (nsec)	Rician K Factor (dB)
L1	416.15	1	0	0	89.30	2.54
		2	401.43	-12.59		
L2	473.31	1	0	0	75.22	6.35
		2	696.47	-19.19		
		3	26.27	-20.28		
L3	478.06	1	0	0		
L4	480.08	1	0	0		
L5	491.00	1	0	0	8.93	6.11
		2	29.03	-14.63		
		3	62.50	-18.27		
L6	518.55	1	0	0	3.54	2.90
		2	31.93	-19		
L7	547.39	1	0	0	4.24	2.90
		2	37.70	-18.86		
L8	564.11	1	0	0	12.60	2.84
		2	91.40	-17.04		

Figure 7: WCC

Figure 8: Hostel

5 SIMULATION RESULTS

The tested BFWA system is simulated under the 8 channel models. The block diagram for the BER performance simulation is displayed in Figure 9. Firstly, we have FBWA system signal source which generates radio frequency (RF) OFDM signal, by random data generation, scrambling, convolutional coding, interleaving, mapping, inverse Fast Fourier Transform, multiplexing, window function addition, and idle insertion based on the IEEE 802.11a Standard. The signal is then transmitted by an antenna with location coordinates, height and gain, going through the channel model with addition of the noise according to the E_b / N_0. A receiver antenna at a location with certain gain then captures the signal. The FBWA receiver that owns full frequency synchronization and reverse operations of FBWA signal source receives the RF signal. The PSDU from the receiver and the PSDU from the signal source is synchronized by delaying the PSDU from the signal source. Both the PSDU are compared to obtain the BER performance. As the FBWA system can only support until 36 Mbps, the simulations are carried out at that data rate over Channel L1-L8.

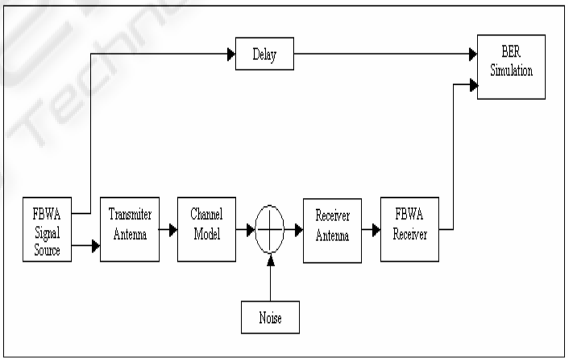

Figure 9: Block Diagram for Simulation

To have an idea on how the BER performance is effected by various parameters seperately, literature study has been carried out. Numerical results from (Yee and Linnartz, 1994) and (Witrisal *et al.*, 1998) revealed that the Rician K-factor has a significant effect on the BER. The BER performance is getting better as the value of K factor is higher at E_b / N_0 higher than 5 dB.

On the other hand, results from (Doufexi *et al.*, 2002) indicated that system performance improves as the RMS delay spread increases, until the excess delay significatly exceeds the guard interval length. This characteristic is due to OFDM exploits the increased frequency diversity that results from high rms delay spread.

Besides, to improve the performance of the system under certain channels, we may sacrifice the speed of the data transmission. The performance of the system increases as we decrease the data rate. From Figure 10, we may observe that the BER performance for the modeled system undergoing channel L1 improving as data rate is lower.

The simulated BER performance results for different channels are illustrated in Figure 11. We found that this system performs better under Channel L1 and L3, where the BER are near 10^{-4} when the E_b/N_0 is in 12 and 14 dB range, comparing with BER of other channels with E_b/N_0 bigger than 16 dB. From our observation, L2 with longer distance and bigger Rician K factor but a smaller rms delay spread have worse performance than L1. Here, the rms delay spread has much effect on the performance. For channel L3 and L4 with single ray, the longer distance link in L4 has worse performance. The effect of rms delay spread can also be seen from channel L2 and L5 with Rician K factor 6 dB and channel L6 and L7 with Rician K factor 2.9 dB. The bigger rms delay spread gives a better performance. The longest distance link in L8 give worst performance although the rms delay spread is bigger than channel L6 and L7.

The BER performances of the system over the channels are found unpredictable without a simulation and measurement. The performance under these channels varies widely although all of the channels are under LOS conditions. The difference of the performances are not only due to delay spread and Rician K-factor of each channel, but also the distance, transmit power, and received signal level of the links.

6 CONCLUSIONS

A high availability of a radio system is not only depending on the design of the equipment, but also the good location of radio antenna sites and a good path planning. This paper highlights a good path planning for a FBWA system. We model 8 LOS channels with a physical propagation model and enhance them with field measurement at the related site. Then, the physical layer of FBWA system is modeled and tested to conform its specifications and standards. This is followed by the simulation on BER performance of the system over the modeled channels using a software simulator tool. BER performance results have been presented and good performance links are identified.

REFERENCES

Clark M. P., 2000, *Wireless Access Network*, John Wiley & Sons. West Sussex P019 1UD, UK.

IEEE 802.11a, 1999, Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band.

Liang G. and Bertoni H.L. 1998. A new approach to 3-D ray tracing for propagation prediction in cities. *IEEE Trans. Ant. Propagation*, vol. 46, no. 6, pp.853-863.

Tang M.K. and Tharek A.R. 2004. Channel Modeling at 5.8 GHz for Fixed Wireless Access. In *WOCN'04, First IFIP International Conference on Wireless and Optical Communications Network.*

Tang M.K and Tharek A.R. 2004. Propagation Prediction Based on Meaurement at 5.8 GHz for Fixed Wireless Access. *ICT'04,11th International Conference on Telecommunication.*

Yee. N and Linnartz J.P. 1994. Controlled Equalization of Multi-Carrier CDMA in an Indoor Rician Fading Channel. In IEEE 44th Vehicular Technology Conference, vol. 3, pp.1665-1669.

Witrisal K., Yong H. K. and Prasad R. 1998. Frequency-Domain Simulation and Analysis of the Frequency Selective Radio Channel for the Performance Analysis of OFDM. In *Proc. 3, OFDM Fachgesprach, Braumschweig, Germany*.

Doufexi A. et al. 2002. A Comparison of HIPERLAN/2 and IEEE 802.11a Wirelss LAN Standards.IEEE Communications Magazine, May 2002, pp. 172-180.

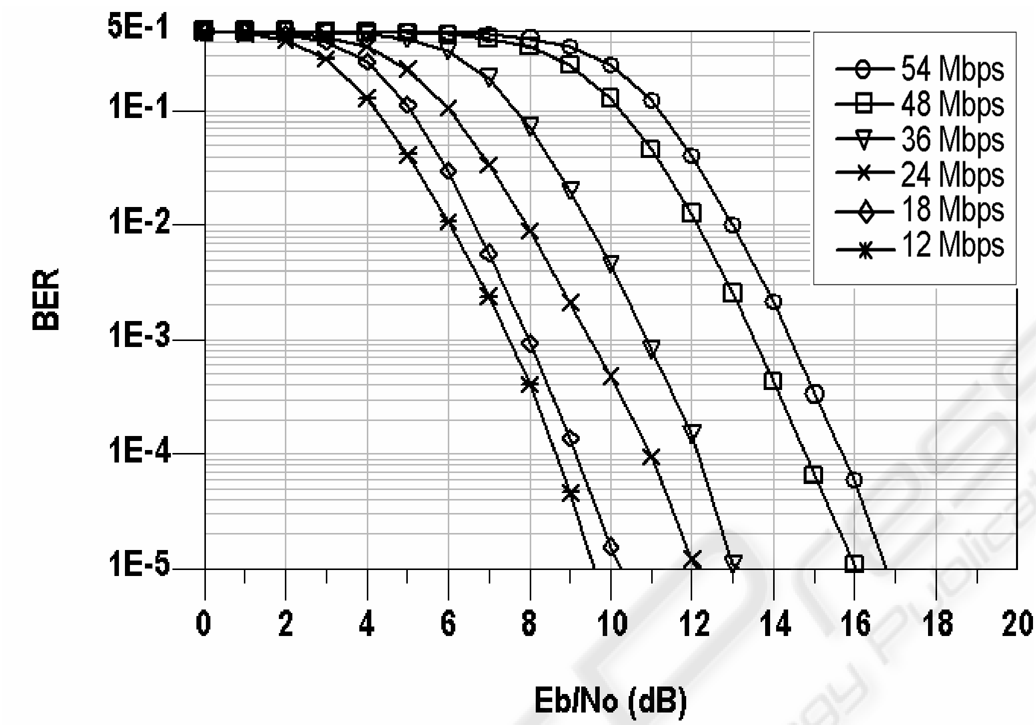

Figure 10: BER Performance For Channel L1

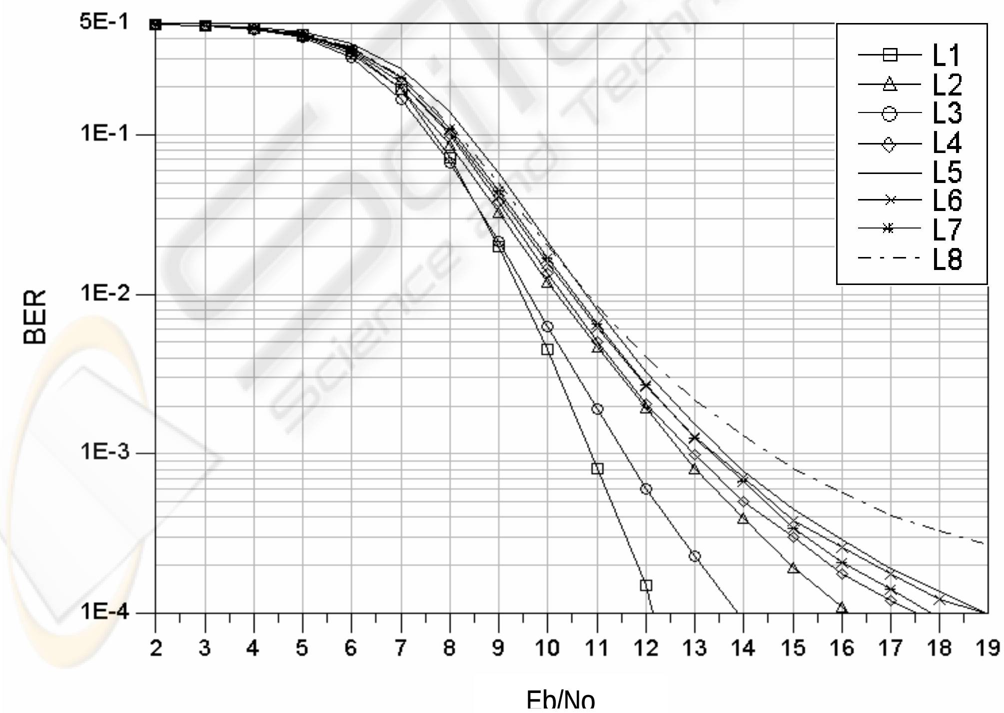

Figure 11: BER Performance For Different Channels