Simulation of Fading Channel and Burst Error Behavior of State-3 Memoryless Markov Model

Tijjani Adam and U. Hashim

Institute of Nano Electronic Engineering,
Universiti Malaysia Perlis (UniMAP)
01000 Kangar, Perlis Malaysia.
E-mail: uda@unimap.edu.my

Abstract - The paper contain a report on simulation of fading channel using Markov Model through a very simple and effective approach, The study established the successful application of Discrete time Simulation in fading channel by applying a tri-states memory-less Markov Model. We generated Four Matlab programs to simulate the Markov Fading Channel and successfully implemented the generated code through the model. Thus, this validates the applicability of the Markov Model in the simulation of fading channel. The probability of error varies according to any change that could happen in the probability of moving from one state to another. Considering 20 points around the standard probability of transition, each point is the average of 100 cycles of the same probability of transition, For Burst Error Behavior of State-3, Simulations have been performed with the data streams consisting of 4.8 Megabits have been directed through the Markov Channel in different test conditions. The length of each error as well as its frequency of occurrence has been recorded. To better conform to industrial application where long data stream would be cut into data-packets of fixed length before transmission, the 4.8 Megabits data stream has been cut into various data-packets sizes of 300 bits, 1200 bits, 4800 bits and 19200 bits for comparison purpose. These particular packet sizes have been chosen in consideration of the use of RC-Interleave in subsequent simulations and for Error-Correction-Coding and Interleaved Coding Scheme. We also studied the burst error behavior of State-3 memory-less Markov Model and presented the use of Error-Correction-Coding with Interleaved scheme which is justified by the illustration of consistently lower Bir-Error-Rate.

Key words: Markov Model, EM transmission, in cellular networks, fading channel, simulation Bir-Error-Rate.

I. Introduction

Fading channel is usually a channel that experiences fading[6-8]. When this fading is due to the multipath propagation is known as multipath fading shown in figure 1. This fading happens due to the dispersion of the signal from transmitting antenna[18,19]. These propagated signals are varying in phase and amplitude and they are causing interference while they reached receiving antenna.

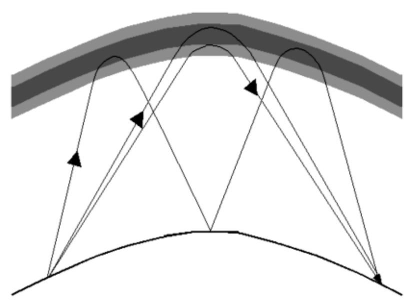

Figure 1: Multipath Fading

This fading is caused by many prominent terrain contours like hills, forests, clumps of building etc between the transmitter and receiver[1-5]. The statistics of large-scale fading provide a way of computing an estimate of path loss as a function of distance.

Small scale fading caused by the superposition or cancellation of multipath propagation signals, the speed of the transmitter or receiver or the bandwidth of the transmitted signal[2]. It is also known as Multipath Fading or Rayleigh Fading. It could be 20-30 dB over a fraction of a wavelength. When the multipath signals arrived at the receiver creates constructive and destructive interference in space. As the receiver is moving through space, it experiences peaks and nulls of multipath fading; often losing the signal monetarily.

A. Markov Model in Fading Channel Simulations

Markov models are some of the most powerful tools available to engineers and scientists for analyzing complex systems but very few take this golden advantage to work with this model. The analysis using this model yields results for both the time dependent evolution of the system and the steady state of the system[14,17]. The name Markov model is derived from one of the assumptions which allows this system to be analyzed; namely the Markov property. The Markov property states: given the current state of the system, the future evolution of the system is independent of its history. The Markov property is assured if the transition probabilities are given by exponential distributions with constant failure or repair rates. In this case, we have a stationary, or time homogeneous, Markov process [14]. The assumptions on the Markov model may be relaxed, and the model may be adapted, in order to analyze more complicated systems. Markov models are applicable to systems with common cause failures and degradation, such as signal fading in wireless or mobile communication system. According Wei Tang [17], finite-state Markov models representing correlated Rayleigh fading channels under the scenarios of spatial diversity and frequency diversity & these models can provide both static and dynamic properties of correlated fading channels, and are very useful for the performance evaluation of diversity systems. Gilbert, Elliot [8-11] and several authors have considered the Markov model, increasing its complexity in terms of states mentioned in the paper of Fulvio [12]. Each state of the channel corresponds to some channel quality and/or response at the receiver. The simplest model is Gilbert channel, a two-state model where the states correspond to total absence of errors and to error occurrence with a prefixed probability, respectively.

Markov models allow one to incorporate into performance analysis the effects of channel memory. Interleaving and coding may be offered as justifications for receivers that assume independent data because they make the received stream appear more uncorrelated [18]. The following figure 2 shows an example of Gilbert and Elliot model[9]. The channel is modeled as a Two-State Markov Chain. Each state duration is memory-less and exponentially distributed.

- The rate going from Good to Bad state is: 1/AFD
- The rate going from Bad to Good state is: 1/ANFD
- (AFD: Avg Fade Duration & ANFD: Avg Non-Fade Duration)

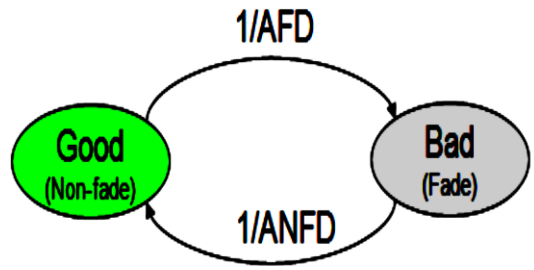

Figure 2: Gilbert and Elliot model

II. RESEARCH METHODOLOGY

MATLab TM has been used extensively in this study. Four MATLab programs have been written to simulate the Markov Fading Channel Simulations have been performed with the following setting, use of simple repetitive Error-Correction-Coding (ECC) scheme where each data bit to be sent will be repeated 3 times after ECC, Use of square row-column (RC) Interleave. MATLab has been used extensively in this study. Four MATLab programs have been written to simulate the Markov Fading Channel, make statistical calculations and present the data in graphical form. The probability of error varies according to any change that could happen in the probability of moving from one state to another[13-15]. Considering 20 points around the standard probability of transition, each point is the average of 100 cycles of the same probability of transition;

For Burst Error Behavior of State-3, Simulations have been performed that data streams consisting of 4.8 Megabits have been directed through the Markov Channel in different test conditions. The length of each error as well as its frequency of occurrence has been recorded. To better conform to industrial application where long data stream would be cut into data-packets of fixed length before transmission, the 4.8 Megabits data stream has been cut into various data-packets sizes of 300 bits, 1200 bits, 4800 bits and 19200 bits for comparison purpose. These particular packet sizes have been chosen in consideration of the use of RC-Interleave in subsequent simulations and for Error-Correction-Coding and Interleaved Coding Scheme. Simulations have been done to examine the BER performances of Bare Data, ECC-padded codes and RC-Interleaved codes in fading channel after error correction. In addition, BER performances have been compared among different data packet sizes of 300 bits, 1200 bits, 4800 bits and 19200 bits. Simulations have been performed for 50 cycles for each different setting[16, 20]

III. Results and Discussion

To calculate the Probability of error, the following equations ware used

$$P_e = \frac{N0.of\ error}{No.of\ bits}$$

$$\sigma = \sqrt{\frac{P_e - P_e^2}{No.of bits}}$$

Relative Error = $\frac{\sigma}{P_e}$

From Markov model in figure4, the probability of moving from state 2 to state 3 is 0.5% and the probability of staying in state 3 is 98%

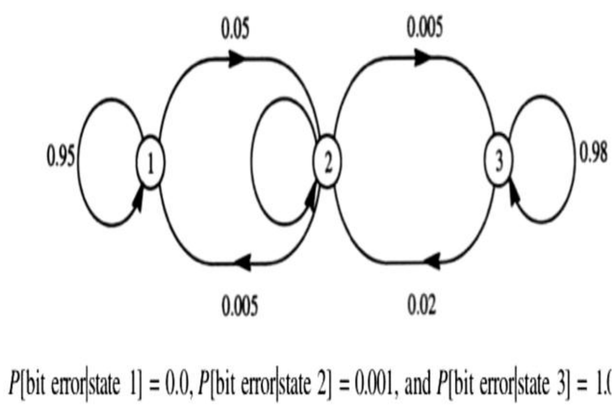

Figure3: Markov Model

Figure4: Probability of transition from state-2 to state -3.

The probability of error varies according to any change that could happen in the probability of moving from one state to another. Considering 20 points around the standard probability of transition, each point is the average of 100 cycles of the same probability of transition. From figure above shows the behavior of error profile versus that of the relative error plotted for different values of probability of transition from state 2 to state 3, for increasing values of probability of transition 0.002 to 0.01, the following can be observed:

- The probability of error increases almost linearly.
- The relative error; as compared to the probability of error; slightly decreases due to the square root in the variance equation where as the latter is proportional to the relative error.
- The graph is not smooth enough, that is because of the small number of iteration and it can be smoothened by increasing the cycles number.

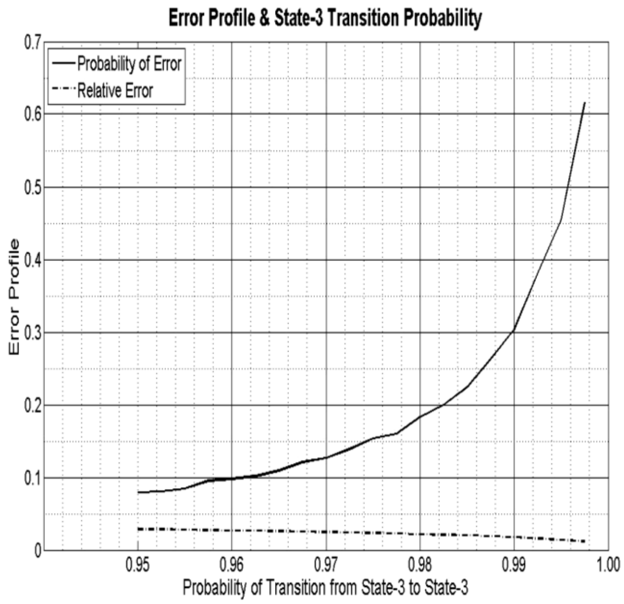

Figure5: Probability of transition from state-2 to state -3.

The figure5: shows the probability of error in state 3 compared to the relative error, for 20 values of probability of staying in state 3, 0.9500 to 0.9975.

- The probability of error rises exponentially with the increase of the probability of staying in state 3.
- The relative error shows minor drop as result of the root square in the variance equation.
- The graph is not that smooth due to the small number of iteration, the bigger number of iteration the smoother the graph is.
- Graph minimum not touching zero, that's because even if the probability of moving to state 3 is set to 0, there still will be errors generated in state 2.
- Graph maximum approaching one but not going to be 1 as the probability of staying in state 3 increases.

The two graphs prove the suitability of the Markov Model application in fading channel simulation

A. Burst Error Behavior of State-3

From the Markov Model in figure 5 shown the following were anticipated

- Most of the errors will be generated in State-3
- Once in State-3, the occurrence of long error burst is highly likely

To better conform to industrial application where long data stream would be cut into data-packets of fixed length before transmission, the 4.8 Megabits data stream has been cut into various data-packets sizes of 300 bits, 1200 bits, 4800 bits and 19200 bits for comparison purpose. These particular packet sizes have been chosen in consideration of the use of RC-Interleave in subsequent simulations.

The figures6(a-d) indicates Short bit-errors have the highest occurrence regardless of the size of data-packet. All the four graphs indicate the 50% of the errors are of less than 68 to 83 bits long depending on the packet size. as the packet size grows, the error points of 50%, 90% and 98% bit-errors move towards the longer burst error. However, the difference is insignificant between 4800 bits and 19200 bits packet size. With longer packet size, the mean value of errors-lengths increases. This is expected as the longer data- packets make longer burst errors possible, larger packet size introduces larger Bit Error Rates (BER). However, the growing trend of BER with longer data-packet seems to stop between 4800 bits and 19200 bits packet size. The errors points at 30 bits, 60 bits, 120 bits and 240 bits in the four graphs suggested the possibilities of errors corrections up to 17.33%, 36.44%, 69.53% and 95.68% with respective packet size if used together with RC Interleave.

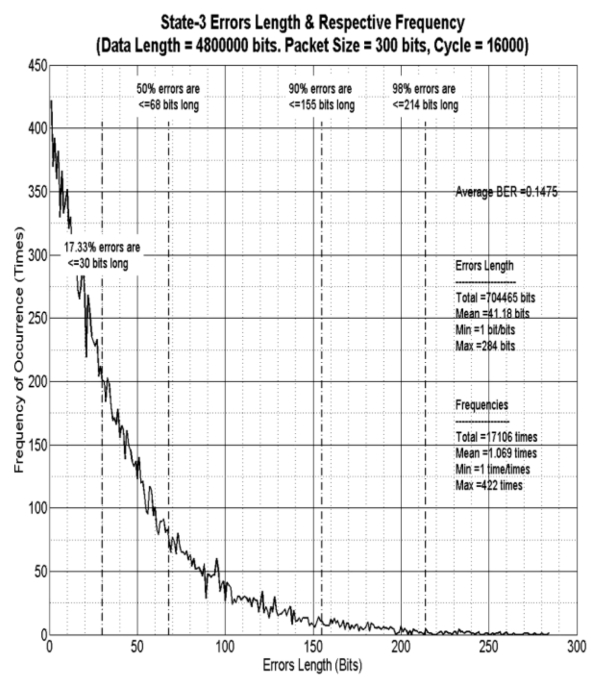

Figure 6a: Burst Error Behavior of State-3

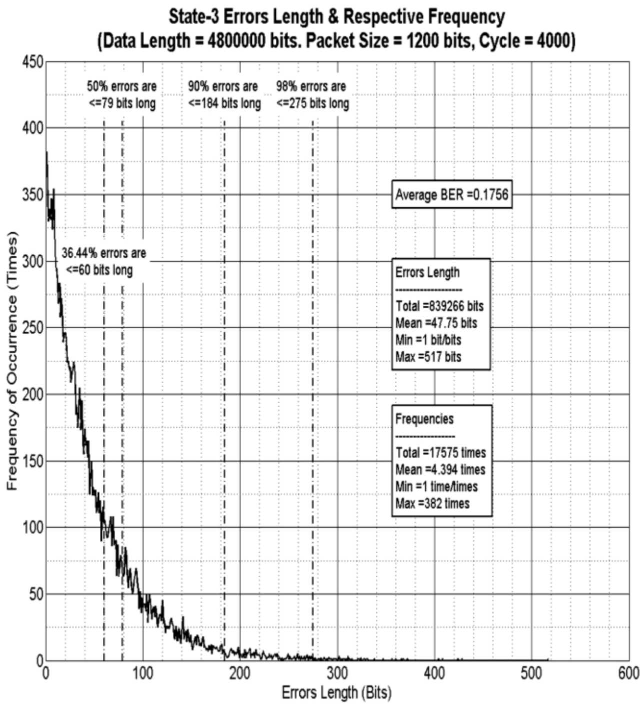

Figure 6b: Burst Error Behavior of State-3

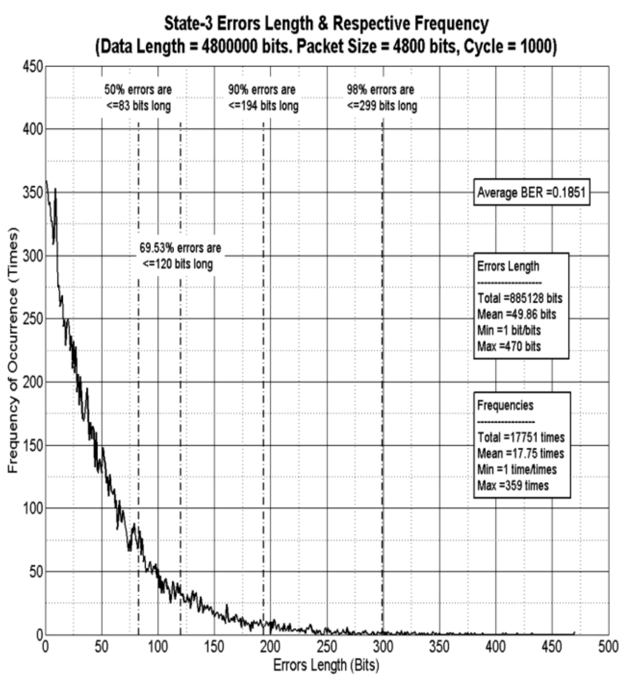

Figure 6c: Burst Error Behavior of State-3

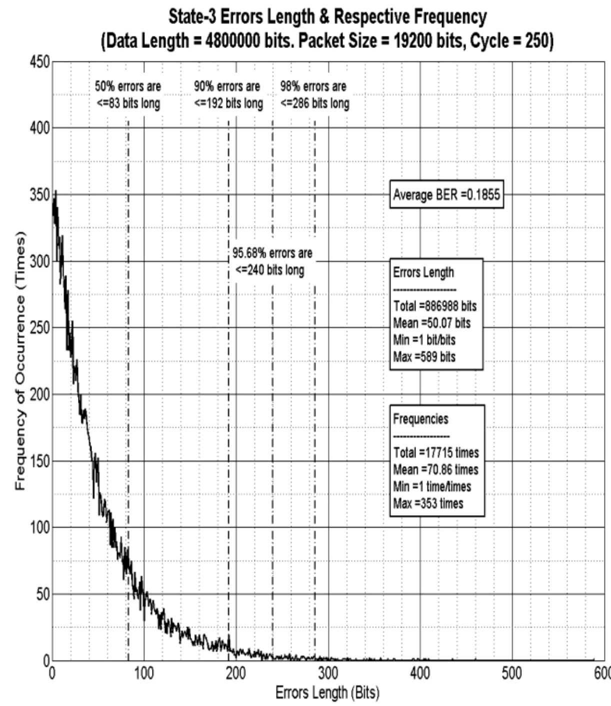

Figure 6d: Burst Error Behavior of State-3

B. Error-Correction-Coding and Interleaved Coding Scheme

Simulations have been done to examine the BER performances of Bare Data, ECC-padded codes and RC-Interleaved codes in fading channel after error correction. In addition, BER performances have been compared among different data packet sizes of 300 bits, 1200 bits, 4800 bits and 19200 bits. Simulations have been performed for 50 cycles for each different setting.

The figures7(a-d) indicate highest average BER for Bare Data (BD), followed by ECC-padded code (ECC) and Interleaved Code (IC).BER performances of ECC (without Interleaved) do not show noticeable improvement compared to BD. This indicates the ineffectiveness of simple repetitive ECC scheme in handling long burst errors in fading channel. Taking into consideration of the greater bandwidth requirement for the longer ECC-padded data, conclusion can be drawn that simple repetitive ECC is not appropriate for a fading channel where long error bursts are highly probable. All graphs display noticeable better BER performance of IC, as compared to ECC. This shows that even a simple RC-Interleaved scheme could improves digital transmission quality in fading channel. There are instances where ECC has better or similar BER performance as compared to IC. These happen in the simulation settings where the data packet sizes are 300 bits and 1200 bits (900 bits and 3600 bits after ECC-padding). This could be due to the insufficient RC-Interleave depth of 30 bits and 60 bits in correcting burst errors which are much longer. Performances of IC improved as data-packet size increases. However, there is no significant improvement of the IC's average BER after the packet size reach 4800 (14400 after ECC-padding) bits. This suggests the existence of a performance improvement limit at this packet size.

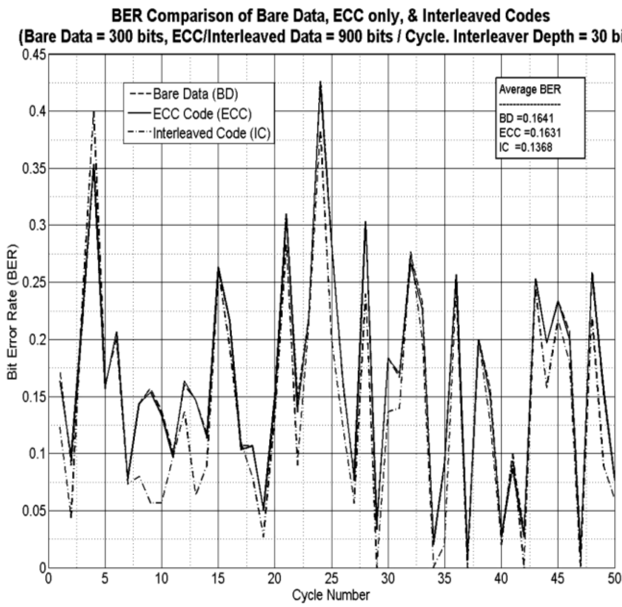

Figure 7a: BER comparison Bare Data with interleave Depth of 30 bits

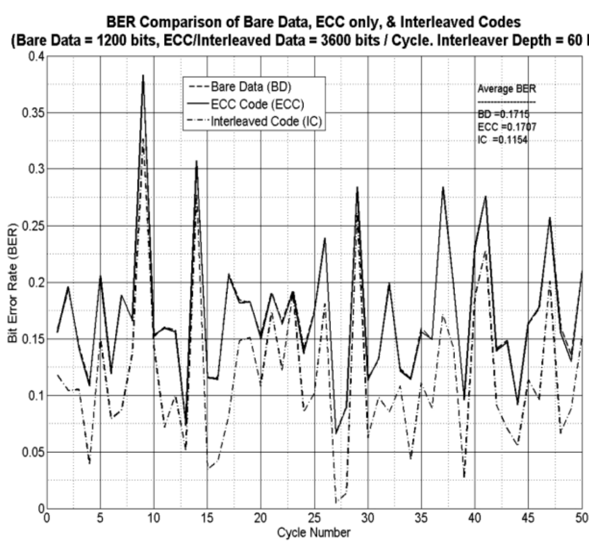

Figure 7b: BER comparison Bare Data with interleave Depth of 60 bits

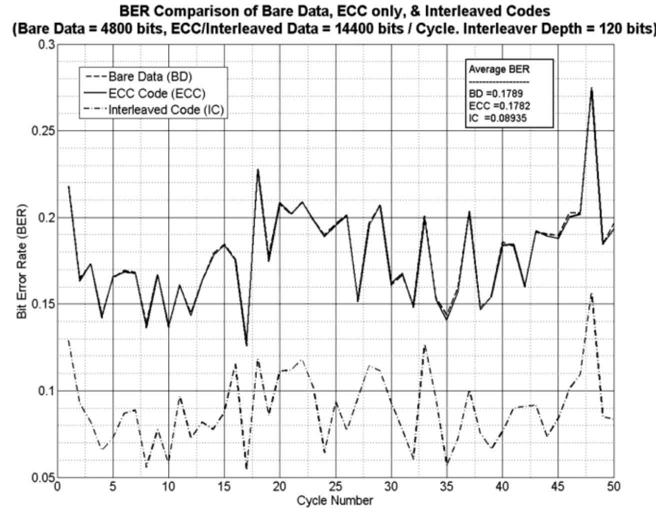

Figure 7c: BER comparison Bare Data with interleave Depth of 120 bits

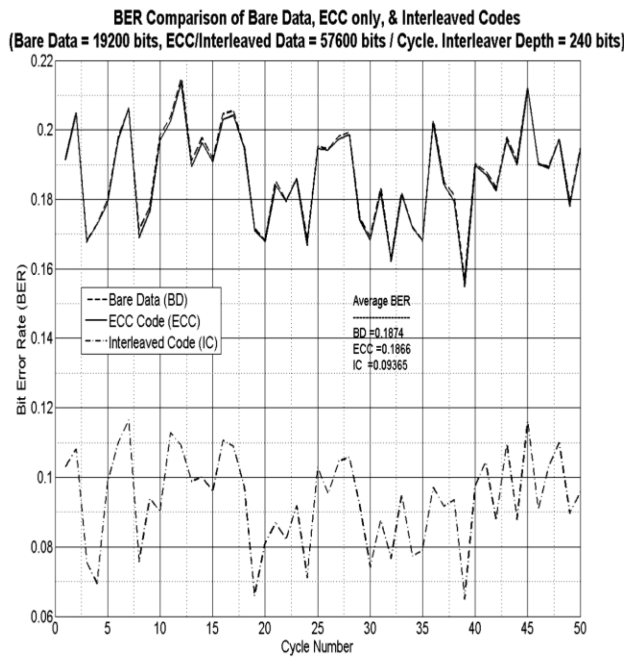

Figure 7d: BER comparison Bare Data with interleave Depth of 240 bits

IV. CONCLUSION

The research established the successful application of Discrete Time Simulation in fading channel by applying a tri-states memory-less Markov Model, study managed to validate the applicability of the Markov Model in the simulation of fading channel by studying its error profile. Secondly, the burst error behavior of State-3 has been studied and presented the use of Error-Correction-Coding with Interleaved scheme has been justified by the illustration of consistently lower Bir-Error-Rate.

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Reference

[1] Anatory, J., Theethayi, ., Thottappillil, R. Power-Line Communication Channel Model for Interconnected Networks—Part I: Two-Conductor System, Power Delivery, IEEE Transactions on (2009) ,(24) 1 pp 118 – 123

[2] S. Galli, T. Banwell, "A Novel pproach to the Modeling of the Indoor Power Line Channel -- Part II: Transfer Function and Its Properties," to appear in the IEEE Transactions on Power Delivery, April 2005

[3] T. Banwell, S. Galli, "A Novel pproach to the Modeling of the Indoor Power Line Channel -- Part I: Circuit Analysis and Companion Model," to appear in the IEEE Transactions on Power Delivery, April 2005

[4] M.Stojanovic, Underwater acoustic communications: design considerations on the physical layer, invited paper, in Proc. IEEE/IFIP Fifth Annual Conference on Wireless On demand Network Systems and Services (WONS), Jan. 2008.

[5] Pechta, Laura E.; Brandenburg, Dale C.; and Seeger, Matthew W. (2010) "Understanding the Dynamics of Emergency Communication: Propositions for a Four-Channel Model," *Journal of Homeland Security and Emergency Management*: Vol. 7: Iss. 1, Article 55

[6]. W. Kumwilaisak, C.-C. J. Kuo, and D. Wu, ``Fading Channel Modeling via Variable Length Markov Chain (VLMC) Technique," IEEE Transactions on Vehicular Technology, vol. 57, no. 3, pp. 1338–-1358, May 2008.

[7]. Matthias Patzold, "Mobile Fading Channels: Modelling,Analysis and Simulation", Published by John Wiley & Sons, 2001.

[8]. Marvin Kenneth Simon, Mohamed-Slim Alouini, "Digital Communication Over Fading Channels" Chapter 2, Published by John Wiley & Sons.

[9]. D. Parsons, The Mobile Radio Propagation Channel. London, U.K.: Pentech, 1992.

[10]. R. Steele, Mobile Radio Communications. London, U.K.: Pentech, 1991.

[11]. G. Babalis and C. N. Capsalis, "Impact of the Combined Slow and Fast. Fading Channel Characteristics on the Symbol Error Probability for. Multipath Dispersionless Channel Characterized by a Small Number of. Dominant Paths", IEEE Trans. on communication, 2002.

[12]. Wireless communications, Chapter: Multipath fading, JPL's Reference Website.

[13]. Markov Model, http://www.markov-model.com/.

[14]. Wei Tang, University of Pennsylvania, **"**Finite-state Markov models for correlated fading channels in wireless communications", 2001.

[15]. E. N. Gilbert, "Capacity of a burst-noise channel," Bell Syst. Tech. J., vol. 39, pp. 1253–1266, Sept. 1960.

[16]. E. O. Elliott, "Estimates of error rates for codes on burst-noise channels," Bell Syst. Tech. J., vol. 42, pp. 1977–1997, Sept. 1963.

[17]. F. Babich, G. Lombardi, "A Markov Model for the Mobile Propagation Channel", IEEE Trans. on Vehicular Technology, F. Babich, G. Lombardi, "A Markov Model for the Mobile Propagation Channel", IEEE Trans. on Vehicular Technology, vol. 49, no. 1, January 2000, pp. 63-73.

[18] Jerry D. Gibson, "A communication Handbook", CRC Press.

[19]. Sklar, Bernard, "Rayleigh Fading Channels in Mobile Digital Communication Systems Part I: Characterization" *IEEE Commun. Mag.*, vol. 35, no. 11, pp. 90-100, July 1997.

[20]. Jeruchim, C., Balaban, P, and Shanmugan, K. Sam, "Simulation of communication systems [electronic resource] : modeling, methodology, and techniques", New York : Kluwer Academic, c2002.