

# Realistic Prediction of BER for Adaptive OFDM Systems

Meiling Luo, Guillaume Villemaud, Jean-Marie Gorce, Jie Zhang

► **To cite this version:**

Meiling Luo, Guillaume Villemaud, Jean-Marie Gorce, Jie Zhang. Realistic Prediction of BER for Adaptive OFDM Systems. Antennas and Propagation (EuCAP), 2013 7th European Conference on, Apr 2013, Gothenburg, Sweden. hal-00920924

**HAL Id: hal-00920924**

**<https://hal.inria.fr/hal-00920924>**

Submitted on 19 Dec 2013

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Realistic Prediction of BER for Adaptive OFDM Systems

Meiling Luo<sup>\*†</sup>, Guillaume Villemaud<sup>†</sup>, Jean-Marie Gorce<sup>†</sup>, and Jie Zhang<sup>\*‡</sup>,

<sup>\*</sup>Ranplan Wireless Network Design, Ltd., Luton LU2 0SX, U.K., E-mail: meiling.luo@ranplan.co.uk

<sup>†</sup>CITI, INSA-Lyon, INRIA, Université de Lyon, 69621 Villeurbanne, France

<sup>‡</sup>Department of Electronic and Electrical Engineering, University of Sheffield, Sheffield S1 3JD, U.K.

**Abstract**—Adaptive OFDM systems improve the spectral efficiency. In this paper, block adaptive modulation is implemented based on the realistic prediction of BER and fading parameters from the MR-FDPF model. The aggregate data rate from block adaptive modulation is compared to that from non-adaptive modulation, and at the end, the data rate gain is obtained.

**Index Terms**—Bit error rate (BER); adaptive modulation; orthogonal frequency-division multiplexing (OFDM) systems

## I. INTRODUCTION

A great need of high data rate services has stimulated the development of wideband wireless communications. One of the facts that wideband wireless communications should face is that wideband wireless channels usually suffer from frequency selective fading. Orthogonal frequency-division multiplexing (OFDM) technology is preferred in wideband wireless systems since it can convert a frequency selective wideband channel into a set of orthogonal frequency nonselective channels [1]. It is of great significance to improve the spectral efficiency due to the scarcity of frequencies. Thus, adaptive OFDM systems are proposed and they have been shown great benefits in improving the spectral efficiency of communication systems. In this paper, we study the adaptive modulation technique for OFDM systems. We first predict a realistic BER of the subcarriers of OFDM systems based on the wideband simulation of the Multi-Resolution Frequency Domain ParFlow (MR-FDPF) model, and then block adaptive modulation is implemented. The aggregate data rate from the block adaptive modulation is compared to that from non-adaptive modulation systems, and at the end, the data rate gain is obtained.

## II. REALISTIC PREDICTION OF BER AND BLOCK ADAPTIVE MODULATION FOR OFDM SYSTEMS

The MR-FDPF model is a deterministic radio propagation model based on the lattice wave automata theory [2]. It is noticed that the MR-FDPF model works in the frequency domain so that it avoids a sufficient number of time iterations which is needed to reach the steady state in the time domain. For more details about the principle of the MR-FDPF model, please refer to [3][4]. The MR-FDPF model has been verified to be capable of predicting the mean power and fading statistics [4][5][6][7][8].

In [6], we have verified that the MR-FDPF model is capable of simulating the wideband multipath fast fading. In this paper,

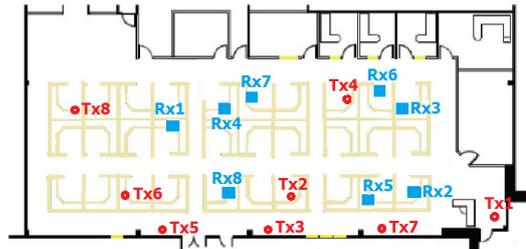


Fig. 1. The measurement scenario.

we make use of this capability of the MR-FDPF model to implement block adaptive modulation for OFDM systems so that a higher data rate can be achieved. In block adaptive modulation technique, all the subcarriers of OFDM systems are first divided into several blocks and then all the subcarriers within a block employ the same modulation scheme [9][10]. In this way, the signaling overhead is reduced.

As in [6], in order to evaluate our proposed approach, we adopt the Stanford's measurement "I2I stationary" scenario as the simulation scenario [11]. The scenario is a typical office environment including 8 transmitters and 8 receivers shown in Fig. 1. We use the measurement data at the bandwidth of 50 MHz centered at 2.45 GHz and the transmit power for each subcarrier is  $-30$  dBm, which implies that we don't consider the adaptive power allocation here. The simulations of the MR-FDPF model are performed at 16 frequency bins which are evenly distributed within the bandwidth of 50 MHz. We consider the OFDM system with 128 subcarriers, so each frequency bin represents 8 subcarriers which are grouped as a block for the block adaptive modulation. Due to the limited space, here we only take the link between Tx7 and Rx1 for example. The wideband multipath fast fading characteristics from the simulation and measurement are compared in Fig. 2. The capability of the MR-FDPF model in simulating the wideband multipath fading characteristics enables us to estimate the Signal-to-Noise Ratio (SNR) and fading parameters of subcarriers. It is important to note that not only the SNR, but also the fading parameters have a big influence on BER [8]. The predicted BER in this paper is more realistic since it takes into account both the SNR and fading parameters.

The predicted BER is used to determine the modulation

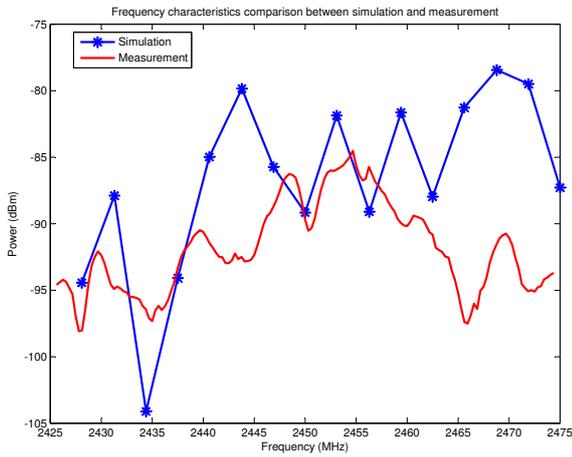


Fig. 2. Frequency characteristics comparison of the link Tx7-Rx1 between simulation and measurement.

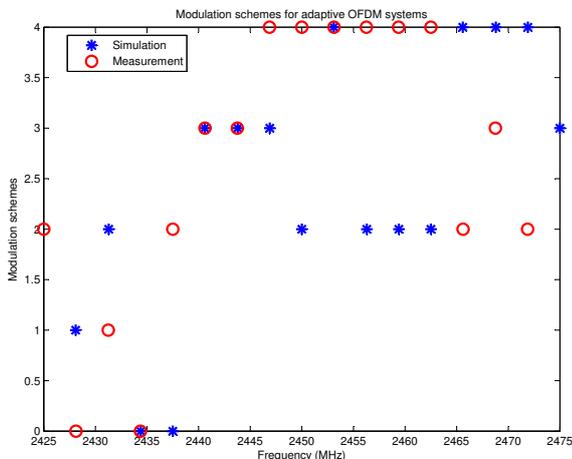


Fig. 3. Modulation schemes for adaptive OFDM systems.

scheme for each block of subcarriers at the threshold of  $10^{-3}$ . Fig. 3 shows the modulation schemes of the block adaptive modulation both from the simulation and measurement. In Fig. 3, the numbers: 1, 2, 3, 4 denote the BPSK, QPSK, 16QAM, 64QAM modulation schemes and 0 denotes none of the four modulations can satisfy the target BER. It is noticed from Fig. 2 and Fig. 3 that both the wideband multipath fast fading and modulation schemes of block adaptive modulation do not fit each other very well from the simulation and measurement. This is because fast fading is very sensitive and random, thus we do not expect them fit exactly, but fit in a statistical sense. Therefore, we compare their aggregate data rate and data rate gain over non-adaptive modulation in the following part.

The raw aggregate data rate is computed by [10]

$$R = \frac{\text{Number of bits per OFDM symbol}}{\text{Time duration of OFDM symbol}} \quad (1)$$

The data rate gain is defined as [10]

$$\text{Gain} = \frac{\text{Data rate from adaptive modulation}}{\text{Data rate from nonadaptive modulation}} \quad (2)$$

TABLE I  
COMPARISON OF AGGREGATE DATA RATE AND DATA RATE GAIN

	Simulation	Measurement
Aggregate data rate 1	159.375 MHz	178.125 MHz
Aggregate data rate 2	100 MHz	112.5 MHz
Data rate gain	1.5938	1.5833

Table. I gives the obtained aggregate data rate from block adaptive modulation (aggregate data rate 1) and that from non-adaptive modulation (aggregate data rate 2) and data rate gain from the simulation and measurement. From Table. I, we can see that the simulation and measurement fit each other very well.

### III. CONCLUSION

In this paper, a realistic BER for adaptive OFDM systems is predicted based on the MR-FDPF model and thus the block adaptive modulation can be implemented. The obtained aggregate data rate from adaptive modulation is compared to that from non-adaptive modulation, and at the end, the data rate gain is obtained.

### ACKNOWLEDGMENT

This work is funded by the FP7 IPLAN Project.

### REFERENCES

- [1] A. Bahai, B. Saltzberg, and M. Ergen, *Multi-carrier digital communications: theory and applications of OFDM*. Springer, 2004.
- [2] P. Luthi, "Lattice wave automata: from radio wave to fracture propagation," Ph.D. dissertation, Computer Science Department, University of Geneva, 24 rue General-Dufour, 1211 Geneva 4, Switzerland, 1998.
- [3] J.-M. Gorce, K. Jaffres-Runser, and G. de la Roche, "Deterministic approach for fast simulations of indoor radio wave propagation," *IEEE Transactions on Antennas and Propagation*, vol. 55, no. 3, pp. 938–948, 2007.
- [4] K. Runser and J.-M. Gorce, "Assessment of a new indoor propagation prediction method based on a multi-resolution algorithm," in *IEEE 61st Vehicular Technology Conference, VTC 2005-Spring*, vol. 1, 2005, pp. 35–38 Vol. 1.
- [5] M. Luo, D. Umansky, G. Villemaud, M. Lafort, and J.-M. Gorce, "Estimating channel fading statistics based on radio wave propagation predicted with deterministic MR-FDPF method," in *5th European Conference on Antennas and Propagation (EuCAP 2011), Rome, Italy, April, 2011*.
- [6] M. Luo, G. De La Roche, G. Villemaud, J. Gorce, D. Umansky, and J. Zhang, "Simulation of wide band multipath fast fading based on finite difference method," in *IEEE Vehicular Technology Conference*, no. 2011, 2011.
- [7] M. Luo, N. Lebedev, G. Villemaud, G. De La Roche, J. Zhang, and J. Gorce, "On predicting large scale fading characteristics with the MR-FDPF method," in *6th European Conference on Antennas and Propagation (EuCAP)*. IEEE, 2012, pp. 2186–2190.
- [8] M. Luo, G. Villemaud, J. Gorce, and J. Zhang, "Realistic prediction of BER and AMC for indoor wireless transmissions," *IEEE Antennas and Wireless Propagation Letters*, vol. 11, pp. 1084–1087, 2012.
- [9] A. Kannu, T. Sivanathan, and S. Subramaniam, "Performance of block adaptive modulation schemes for ofdm based wlan systems," in *2002 IEEE International Conference on Personal Wireless Communications*. IEEE, 2002, pp. 6–10.
- [10] F. Edalat, "Real-time sub-carrier adaptive modulation and coding in wideband ofdm wireless systems," Ph.D. dissertation, PhD thesis, Massachusetts Institute of Technology, 2008.
- [11] N. Czink, B. Bandemer, G. Vazquez-Vilar, A. Paulraj, and L. Jalloul, "July 2008 radio measurement campaign: Measurement documentation," Stanford University, Smart Antennas Research Group, Tech. Rep., July 2008.