# Design and Development of HiperLAN/2 WLANs Based Multiwavelet Signals using Adaptive Antennas Algorithm

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**Abstract**

In this paper a simple adaptive antenna idea, consisting of multiple independent omni directional receiver antennas and the ZF (Zero Forcing) algorithm for the adaptive signal processing, is applied to the HiperLAN/2 WLANs based Orthogonal Frequency-Division Multiplexing OFDM, Discrete Multiwavelet Transform (DMWT) and its performance is evaluated at link level. MATLAB modeling demonstrated that the performance with adaptive receiver antennas has a remarkable degradation in the packet (PDU or PSDU) error rate (PER) compared to without using adaptive receiver antennas due to the considerable channel models. With adaptive receiver antennas, Carrier-to-Noise Ratio (C/N) improvement compared to without using adaptive receiver antennas is achieved. The performance of the system can more improve by increasing the number of antennas at receiver.

**Keywords:** Network, HiperLAN/2, Adaptive, OFDM, DMWT, IDMWT.

## 1. Introduction

The BRAIN development is working towards a broadband radio access system with the aim of integrating 2G, 3G, 4G and broadband WLAN systems during a general IP based network platform (Mohr, 2000). Internet access and high data rate services make wide demands on wireless communications systems. Third generation (3G) cellular mobile radio networks like UMTS (Universal Mobile Telecommunications System) are in the position to provide bit rates in the order of 2 Mbps. Their early deployment will start in 2001 in order to supplement the worldwide effectively operating second generation (2G) systems by new and more influential services. However, since 3G systems are constrained by wide area coverage and scarce spectrum, their performance is not enough for numerous applications. High speed wireless local area networks (WLANs) are specially designed to provide high bit rates for local and short range communications. Consequently, broadband WLANs are perfectly suited to complement 3G systems in hot spots. HiperLAN/2 (Baier, 1997, A. Kundu, 2008) (see [6]) is a standard for a wireless local area network (WLAN), that has been developed by the European telecommunications standards institute (ETSI). HiperLAN/2 provides a high transmission speeds from 6 to 54 Mbit/s. This speed is essential to meet the actual condition for –in example– internet access and hence it is expected that the standard will broaden its market share in the next few years (Baier, 1997, A. Kundu, 2008)[6]. in the similar framework, an ad-hoc air interface is being developed based on HiperLAN/2 (H/2), a new European standard specified by the ETSI (European Telecommunications Standards Institute) project BRAN (Broadband Radio Access Networks), which operates in the 5 GHz band and provides bit rates of at least 20 Mbps for local and short range communications . In order to fulfill the necessities on quality of service (QoS) and IP support dictated by upper layers, according to the top down approach adopted within the project, the BRAIN air interface includes a series of enhancements with respect to the reference H/2 system at the convergence layer as well as at the DLC and the physical layer (Edgar Bolinth, 2000)[1]. In this paper, the physical layer and the DLC are considered. In particular, some of the enhancements investigated within BRAIN are discussed. The main purpose of the techniques used at the physical layer is to increase the spectrum efficiency and hence offer improved radio link performance to the upper layers, which have to meet certain Quality of Service (QoS) necessities specified according to the top down approach just mentioned(Edgar Bolinth, 2000) [1]. The operation of adaptive antennas is considered to be one of the most significant measures to increase capacity in cellular mobile radio systems and is currently studied worldwide (Bing, 2000, Baier, 1997, Lu, 2004, Yuan Li, 2013)[5-11]. Adaptive antenna techniques are able of reducing the required transmission power and combating interference. As a result, the application of adaptive antennas to HiperLAN/2 within the BRAIN project seems to be inescapable and very promising with respect to system efficiency. A variety of adaptive antenna ideas exist and their applicability is various (Baier, 1997) [6]. The profit of adaptive antenna techniques applied to the receiver is the enhancement of the receiver's performance by exploiting the diversity information contained in the received signals of the multiple antennas. Depending on the antenna characteristics and their arrangement different basic diversity effects like the separation, the reuse or the introduction of new signal paths can be exploited (Baier, 1997, A. Kundu, 2008)[6]. This paper presents a basic adaptive receiver antenna idea, which consist of multiple omni-directional receiver antennas and the ZF algorithm (Klein, 1996, Hyunwook Yang and Seungwon Choi, 2013, Lie-Liang Yang, 2008 )[12] applied to the HiperLAN/2 air interface. The antennas are arranged in a macro structure, i.e. they are so far apart, at least numerous wavelengths that at each of the antenna locations different wave fronts impinge. This macro structure based concept enables the reception of signals over extra paths and, consequently, provides spatial macro diversity (Baier, 1997, A. Kundu, 2008)[6]. This paper is organized as follows. In section 2 the system model is described. Section 3 describes summarizes the results. Finally, Section 5 concludes the paper.

## 1. System Model

In this part shows the basic discrete time of OFDM based discrete multiwavelet transform system for multiple receiver antennas.

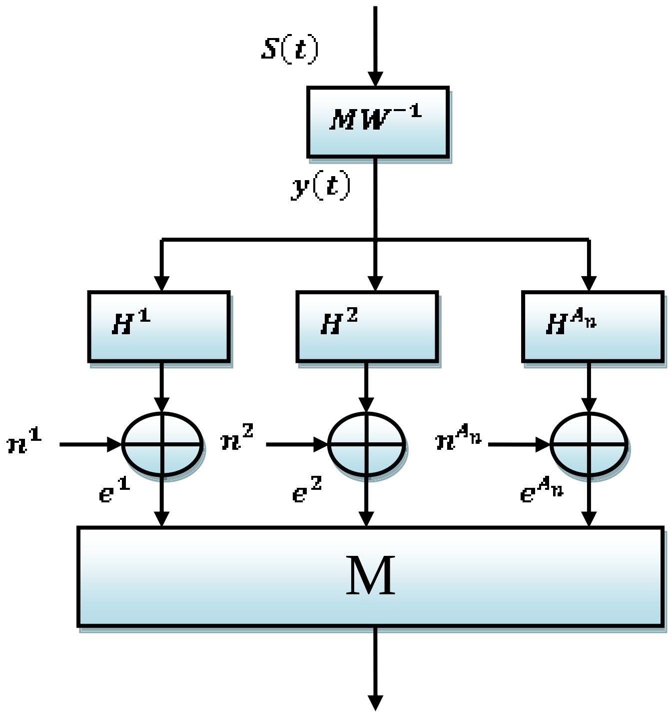


Figure. 1: OFDM multi antenna system model based multi wavelet signals

The data vector $s(t) = (s(t)_1, s(t)_1 \cdots s(t)_N)^T$ to be transmitted consists of $N$ complex modulation symbols $s(t)_i$ which are processed in parallel by an $N$-point Inverse Discrete Multiwavelet Transform (IDMWT), represented by the IDMWT matrix $MW^{-1}$.The output $y(t) = (y(t)_1, y(t)_1 \cdots y(t)_N)^T$ of the IDMWT is transmitted during the $A_n$ mobile radio channels between the single antenna of the transmitter and the $A_n$ antennas of the receiver. Each of the $A_n$ channels is characterized by its particular impulse response

$$h^{An} = \left(h_1^{a_n}, h_2^{a_n}, \dots h_N^{a_n}\right)^T, a_n = 1 \dots A_n. \qquad (1)$$

With the interference vector

$$n^{an} = (n_1^{an}, n_2^{an} \dots n_N^{an})^T, a_n = 1 \dots A_n. \qquad (2)$$

We get the received signal vector:

$$e^{a_n} = (e_1^{an}, e_2^{an} \dots e_N^{an})^T, a_n = 1 \dots A_n. \qquad (3)$$

At the $A_n - th$ antenna element. The channel matrices $H^{An}$ , $a_n = 1 \dots A_n$ , of all channels are arranged in the $A_n$ $NXN$ total channel matrix:

$$H = \left(H_1^{(1)T}, H_2^{(2)T}, \dots H_N^{(A_n)T}\right)^T, a_n = 1 \dots A_n. \qquad (4)$$

Also, the noise vectors $n^{an}, a_n = 1 \dots A_n$ are combined to the total noise vector:

$$n = \left(n^{(1)T}, n^{(2)T} \dots n^{(A_n)T}\right)^T \qquad (5)$$

Of length $A_n N$, and the received signal vector $e^{a_n}$, $a_n = 1 \dots A_n$ , are arranged in the total received signal vector

$$e = \left(e^{(1)T}, e^{(2)T} \dots e^{(A_n)T}\right)^T \qquad (6)$$

of length $An\ N$ . Using (4), (5) and (6) the OFDM transmission can be expressed in matrix vector notation as follows:

$$e = H\ MW^{-1}\ s(t) + n \qquad (7)$$

Based on the linear transmission model of (7) the estimates $\hat{s}(t) = (\hat{s}(t)_1, \hat{s}(t)_1 \dots \hat{s}(t)_N)^T$ of the transmitted data vector $s(t)$ are obtained by solving the detection problem

 

$$\hat{s}(t) = M\vec{e} \quad (8)$$

using linear detection algorithms (Baier, 1999) [11] which are represented by *M* in (8). In order to specify the ZF equalizer the following notations are introduced:

$\vec{h}^{A_n} = MW\, h^{A_n}$ is the frequency response of channel $A_n$, $\vec{n}^{A_n} = MW\, n^{A_n}$ and $\vec{e}^{A_n} = MW\, e^{A_n}$ are the interference vector and the received signal vector of the $A_n - th$ antenna in the frequency domain, respectively. The total interference vector $\vec{n}$ and the total received signal vector $\vec{n}$ are building according to (5) and (6), correspondingly. Furthermore, the matrix

$$\vec{H}^{A_n} = MW\, H^{A_n} MW^{-1} = diag\left(h_1^{-a_n}, h_2^{-a_n} \ldots h_N^{-a_n}\right) \quad (9)$$

represents the $A_n - th$ channel in the frequency domain and the respective total channel matrix is

$$\vec{H} = \left(\vec{H}^{(1)T}, \vec{H}^{(2)T} \ldots \vec{H}^{(A_n)T}\right)^T \quad (10)$$

Lastly, after introducing the covariance matrix

$$\vec{r}_n = E\{\vec{n}\,\vec{n}^{*T}\} \quad (11)$$

The ZF equalizer for the considered OFDM system becomes

$$\hat{s}(t) = \left(\vec{H}^{*T}\vec{r}^{-1}\vec{H}\right)^{-1}\vec{H}^{*T}\vec{r}^{-1}\vec{e} \quad (12)$$

Since $\vec{H}$ is composed of simple diagonal matrices, the detection problem of (12) may be simplified by considering $\vec{r}_n$ in more detail. Utilizing

$$\vec{r}^{(u,v)} = E\left\{\vec{n}^{(u)}\vec{n}^{(v)*T}\right\}, u, v = 1 \ldots A_n \quad (13)$$

$\vec{r}_n$ can be expressed as

$$\vec{r}_n = \begin{bmatrix} \vec{r}_n^{(1,1)} & \cdots & \vec{r}_n^{(1,A_n)} \\ \vdots & \ddots & \vdots \\ \vec{r}_n^{(A_n,1)} & \cdots & \vec{r}_n^{(A_n,A_n)} \end{bmatrix} \quad (14)$$

Assuming that the interference at different antennas is uncorrelated, only the main diagonal of (14) remains. furthermore, if the interference on dissimilar subcarriers is uncorrelated, then

$$\vec{r}_n^{(a_n,a_n)} = diag\left(\left|\vec{n}_1^{a_n}\right|^2, \left|\vec{n}_2^{a_n}\right|^2 \ldots \left|\vec{n}_N^{a_n}\right|^2\right), \quad a_n = 1 \ldots A_n \quad (15)$$

i.e. $\vec{r}_n$ is furthermore a diagonal matrix, consequently, under the given assumptions the detection problem of (12) can be simplified, and with the SNRs

$$\hat{s}(t)_i^{a_n} = \left\{\left|\vec{h}_i^{a_n}\right|^2 / E\left|\vec{n}_i^{a_n}\right|^2\right\}, a_n = 1 \ldots A_n \quad (16)$$

At the $A_n$ antenna elements the estimates $\hat{s}(t)_i\; i = 1 \ldots N$ of $\hat{s}(t)$ are given by

$$\hat{s}(t)_{i,ZF} = \sum_{a_n=1}^{A_n} \hat{s}(t)_i^{a_n}\vec{h}_i^{a_n\,-1}\vec{e}_i^{a_n} \Big/ \sum_{a_n=1}^{A_n}\hat{s}(t)_i^{a_n}, \quad i = 1 \ldots N \quad (17)$$

Separately of each other, i.e. a subcarrier-wise detection is probable

## 2. Simulation Results

The design of the adaptive antennas algorithm is evaluated at the link level in terms of the PDU (Protocol Data Unit) Error Rate (PER) vs. Signal-to-Noise-Ratio (SNR). In this simulation the least robust mode (64 QAM, Rc = 3/4, Rd = 54Mbps) are considered. In Figure. 2, which shows the results for channel model A the gain by doubling the number of antennas from one to eight is 22.4 dB, 11.5 dB,7dB and 4.9 dB in the case of 54 Mbps and 5.7 dB, 5.2 dB and 4.5 dB in the case of 6 Mbps at the target PER of $10^{-3}$ . These high gains are explained as follows: Doubling the number of antennas yields an SNR increase of 3 dB, since the noise at different antennas is uncorrelated. Additionally, frequency diversity is provided on the particular subcarrier, since the different channels are uncorrelated. The achieved gain due to frequency diversity, since the capability of this mode to correct errors on weak subcarriers by Forward Error Correction (FEC) is relatively low. In Figure. 3, which shows the results for Channel E the gain by doubling the number of antennas from one to eight is 28.2 dB, 18.1 dB,12.5dB and 8.5 dB in the 54 Mbps at the target PER of $10^{-3}$. Figure. 3 shows the results for channel E, which provides multipath diversity, but also introduces inter-symbol interference (ISI) and, therefore, inter-carrier interference (ICI) due to the large delay spread. For the 54 Mbps mode the degradation by the ICI is higher than the gain due to multipath diversity. Therefore, this mode performs worse than with model A. With increasing number of antennas the benefits of multipath diversity decrease. In Figure. 3 the achieved gain by doubling the number of antennas is higher than in the case of Figure. 2, since the ICI is also reduced by the adaptive antenna concept. With increasing number of antennas the degradation caused by the ICI decreases.

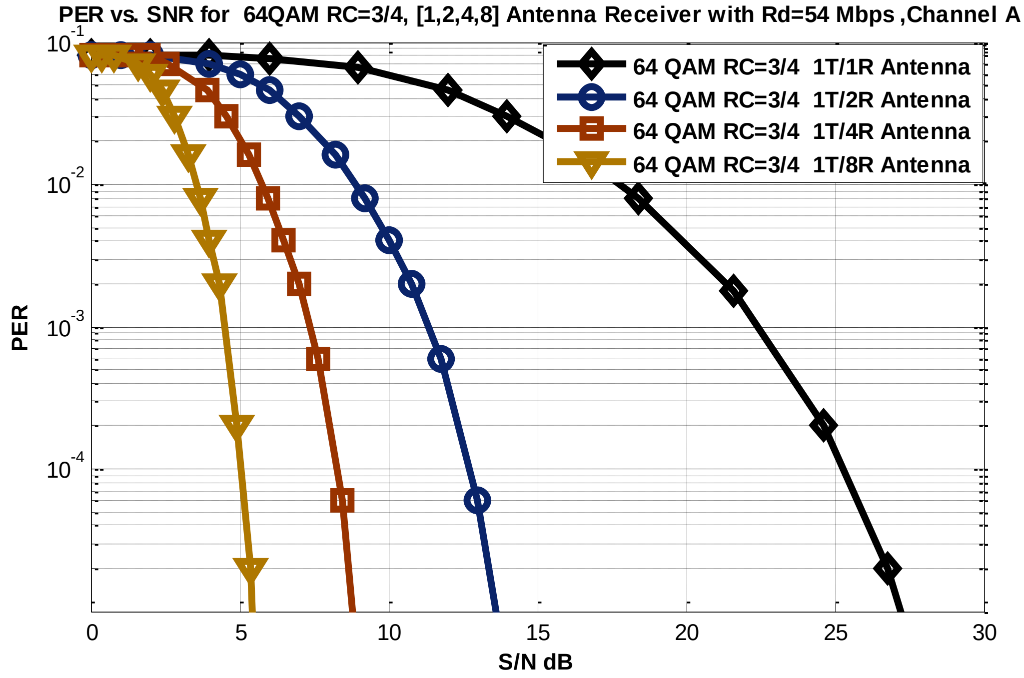


Figure. 2: PER vs. SNR for [1, 2, 4, 8] antennas with Rd= 54 Mbps Channel A

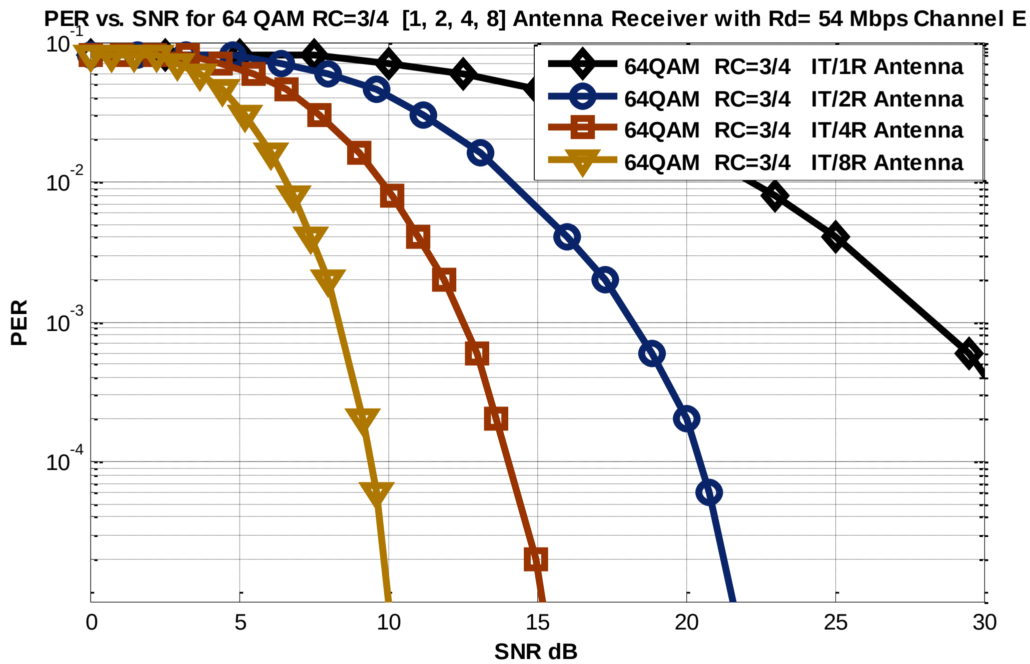


Figure. 3: PER vs. SNR for [1, 2, 4, 8] Antennas Receiver with Rd = 54 Channel E

## 3. Conclusion

Performance results in terms of PER have been presented for enhancement HIPERLAN/2 standard, and for all transmission modes for the case of transmission over different channels. The means contribution of this paper is the implementation of the adaptive antennas in HIPERLAN/2 transceiver based OFDM- DMWT structure PHY-layer which was proposed, simulated, and tested. It has been shown that the considered adaptive antenna concept improves the link level performance of HIPERLAN/2 significantly. Using only 1, 2, 4 and 8 antennas enables the usage of the 54 Mbps mode with channel A and E, which would be impossible with a single antenna. However, the presented results are upper bounds due to the ideal assumptions. Nevertheless, justified by the high maximum gain, the authors expect that this adaptive antenna concept very significantly improves also the performance of a real HIPERLAN/2 system. It can be concluded that this structure achieves much lower bit error rates. In A and Channels, simulations proved that the proposed adaptive antenna design achieved much lower bit error rates and robust for multipath channels.

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