HIPERLAN/2: OFDM SIMULATION USING SIMULINK

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Abstract- Orthogonal Frequency Division Multiplexing (OFDM) is a new digital modulation technique, which consists of transmitting a data stream on several carries instead of using single carrier. It is adopted in several recent digital wireless broadcast and network standards, including HiperLAN/2, IEEE802.11a and Digital Audio Broadcasting (DAB) [1].
This project paper will explore of the use of Simulink to model features of OFDM receiver design. This thesis will also discuss the implementation of OFDM in HiperLAN/2 by simulation using Simulink to model features of OFDM receiver designs, in packet based and in continuous transmission systems, including synchronization and channel compensation problems.

1. HiperLAN/2

1.1 Introduction To HiperLAN/2 Wireless Communication

The aim of several standardization efforts, including Bluetooth, IEEE 802.11 and GPRS is to meet the requirements being put on wireless data communication. HiperLAN/2, which is being specified by the ETSI BRAN project, will provide data rate up to 54 Mbits/s for short range (up to 150m) indoors and outdoors environments [2].

Before standardization work on HiperLAN/2, ETSI has developed the HiperLAN/1 which is standard for ad hoc networking of portable devices. Although HiperLAN/1 provides a means of transporting times bounded services, it does not control or guarantee QoS on the wireless link.

The HiperLAN/2 standard is a complement to present day wireless access system, giving high data rates to end-users in hot spot areas. Compared to other cellular system, the outdoor mobility of hiperLAN/2 is limited. Typical application environments are offices, homes, exhibition halls and airports.

1.2 Protocol Architecture and Layers

The protocol is divided into a control plane part and a user plane part following the semantics of ISDN functional portioning; i.e. user plane includes functions for transmission of traffic over established connections, and the control plane includes function for the control of connection release, and supervision.

The HiperLAN/2 protocol has three basic layers; Physical Layers (PHY), Data Link Control Layer (DLC) and the Convergence Layer (CL).

1.2.1 Physical Layer

The data units to be transmitted via the physical layer of hiperLAN/2 are bursts of variable length. Each burst consists of a preamble and a data field.

Orthogonal Frequency Division Multiplexing (OFDM) has been selected as the modulation scheme for HiperLAN/2, due to good performance on highly dispersive channels [3]. In term of sensitivity and performance when subjected to co-channel interference at a bit rate of 25 Mbits/s, coherent OFDM outperforms single-carrier modulation by 2 to 3 db [4]. Single carrier modulation cannot efficiently support high bit rates; this is important factor since HiperLAN/2 is required to support much higher bit rates.

Seven physical layer modes have been specified (Table 1). Six of the physical layer modes are mandatory; 64 QAM is optional. Each physical layer burst includes preamble, of which there are three kinds for:

1. The broadcast control channel;
2. Other downlink channels;
3. The uplink and the random-access channel.

Mode	Modulation	Code Rate	PHY Bit Rate
1	BPSK	½	6 Mbit/s
2	BPSK	¾	9 Mbit/s
3	QPSK	½	12 Mbit/s
4	QPSK	¾	18 Mbit/s
5	16 QAM	9/16	27 Mbit/s
7	16 QAM	¾	36 Mbit/s
8	64 QAM	¾	54 Mbit/s

Table 1: Physical Layer Modes Of HiperLAN/2

1.2.2 Data Link Control Layer

The DLC layer consists of a radio link control (RLC) sub layer, an error control (EC) protocol, and a MAC protocol.

RLC is used for exchanging data in control plane between an access point and a mobile terminal. The terminal can request a dedicated control channel for setting up radio bearers. Within the specification, radio bearers are referred as DLC connections.

2. Mobile Radio Environment

2.1 Attenuation

Attenuation is the drop in the signal power when transmitting from one point to another. It can be caused by the transmission path length, obstructions in the signal path, and multipath effects.

2.2 Multipath Propagation

Radio waves may also reflected, from a hill, a building and a truck. In some cases, the reflected signal is significantly attenuated and sometimes almost all the radio energy is reflected. The effect will produce many different paths between the transmitter and receiver. This is known as a multipath propagation.

High frequencies reflect better than lower frequencies, which tend to penetrate. The resultant waves from different paths can be constructive or destructive depending on the position, so signal change overtime when moving. This is called frequency selective channel.

2.2.1 Delay Spread

For an impulse transmitted at the cell site, by the time this impulse is received at the mobile unit, it is no longer an impulse. Instead a pulse with a spread width that is called delay spread. The delay spread causes symbol to overlap with proceeding and symbols producing intersymbols interferences.

2.2.2 Intersymbols Interference (ISI)

Multipath manifests itself as fading at low data rates and as intersymbols interference (ISI) at high data rates. As the symbol rate is increased in a multipath channel, the received symbols increasingly interfere with one another, placing an upper limit on the rate at which data can be transmitted without some form of ISI mitigation.

2.2.3 Rayleigh Fading

Rayleigh fading is the second main effect of multipath propagation. The reflected radio wave may undergo drastic alteration in some of its fundamental characteristics, particularly phase and amplitude.

Consider a transmitted signal $s(t) = A \cos 2\pi fct$ through a fading channel. The receiver signal can be expressed as (ignoring the effects of noise):

$$y(t) = A\sum_{i=1}^{N} a_i \cos(2\pi fct + \theta i)$$

where

- a_i is the attenuation of the i^{th} multipath component
- θi is the phase-shift of the i^{th} multipath component

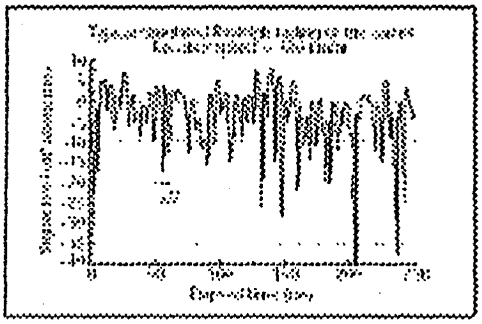

Figure 1: Rayleigh Fading Channel

3. Orthogonal Frequency Division Multiplexing (OFDM)

OFDM is a multi carrier transmission technique, which divides the available spectrum into many carriers, each one being modulated by a low rate data stream. OFDM is similar to FDMA in that the multiple user access is achieved by subdividing the available bandwidth into multiple channels that are then allocated to users. However, OFDM uses the spectrum much more efficiently by spacing the channels much closer together. This is achieved by making all the carriers orthogonal to one another, preventing interference between the closely spaced carriers.

The main idea behind OFDM is to split the data stream to be transmitted into N parallel streams of reduced data rate and to transmit each of them on a separate sub carrier. These carriers are made orthogonal by appropriately choosing the frequency spacing between them. Since the orthogonality will ensure that the receiver can separate the OFDM sub carriers, and a better spectral efficiency can be achieved than by using simple frequency division multiplex.

3.1 Limitation of Bandwidth

The frequencies used in OFDM are regularly spaced in the spectrum required; so the time domain signal $x_n[k]$ has to be limited in the frequency domain. For this reason, a convolutional will be made between the signal and a window function that has a spectrum limited exactly on the required one.

3.2 Adding a Guard Period to OFDM

One of the most important properties of OFDM transmission is the robustness against multipath delay spread [5]. This is achieved by having a long symbol period, which minimizes the inter-symbol interference. The level of robustness can in fact be increased even more by addition of a guard period between transmitted symbols.

3.3 Wideband Transmission on a Single Carrier

When transmitting wideband on frequency selective channels, equalization must be performed in order to avoid intersymbols interference. Equalization tries to make the channel flat. In order to do that channel state information is needed. Training sequences have then to be transmitted periodically to estimated channel [6].

4. Result And Discussion

This model used is based on the HiperLAN/2 system; with 48 data sub carriers and four pilots modulated using 64-IFFT, and a cyclic prefix of 16 samples (Figure 1). This gives OFDM symbol duration of 4µs and resistance to delay spreads up to 0.8µs. Running this model will show the characteristics flattop spectrum of OFDM systems (Figure 2).

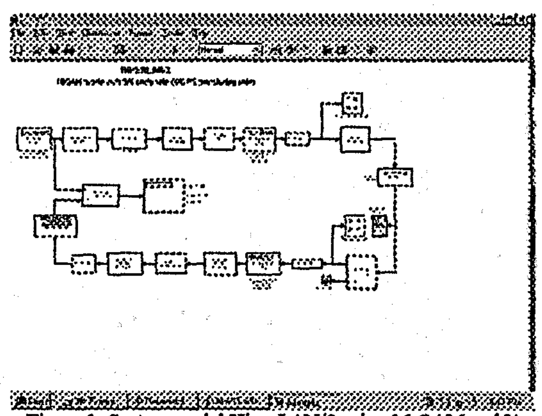

Figure 1: System model HiperLAN/2 using 16 QAM and ¾ punctured code

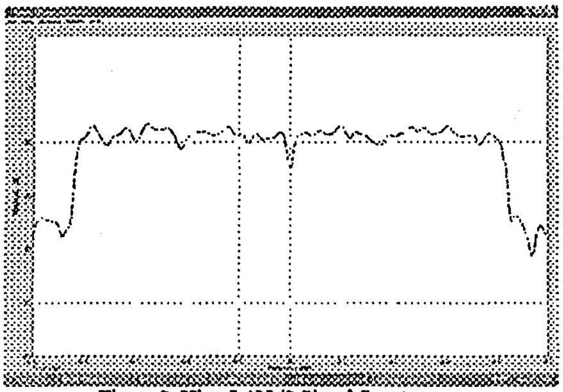
Figure 2: HiperLAN /2 Signal Spectrum

4.1 Synchronization

The receiver must synchronize to the incoming blocks to IFFT-modulated samples. In a packet-based system a known preamble sequence can be used to initialize the symbol-timing block. In a continuous-transmission system the repetition of the cyclic prefix may instead be used to acquire the symbol timing via autocorrelation. Residual timing offset may be compensated after the receiver FFT, as it does not affect the orthogonality of the sub carrier [7].

4.2 Channel Compensation

In a packet-based system the preamble sequence can be used for channel estimation. At the start of a transmission, a training phase is used in which the compensator weights are fixed.

The bit error rate can be minimized by compensating channel phase effect only in a coded OFDM system using PSK. If coding is applied across the sub carriers and soft decoding is used, then the sub carriers in deep fade are automatically given less weight in decoding. However, if compensation for magnitude is also applied, these sub carriers are given full weight in the decoding despite their much worse SNR- the compensation effectively just boost the noise.

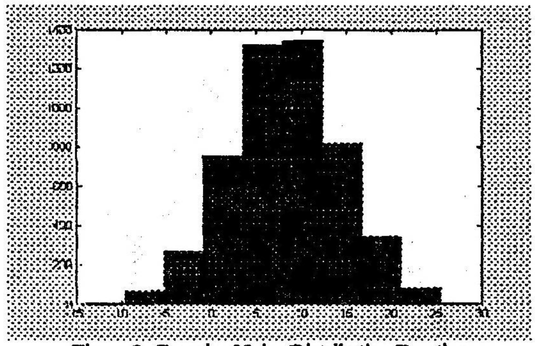
Figure 3: Gaussian Noise Distribution Function

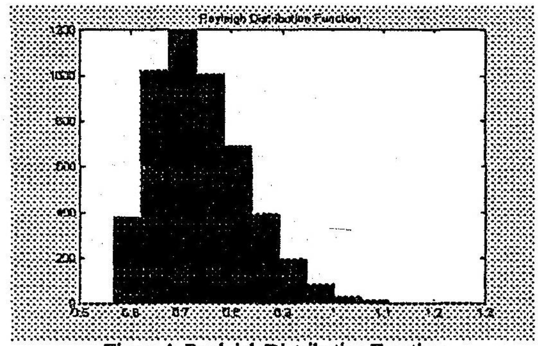
Figure 4: Rayleigh Distribution Function

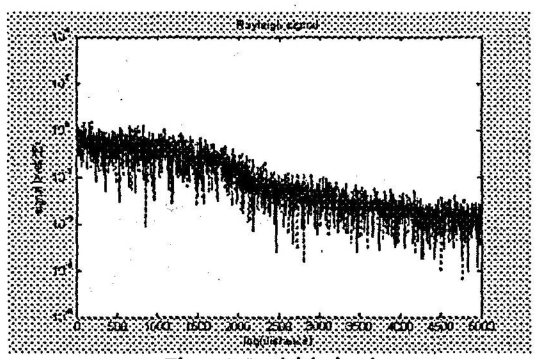
Figure 5: Rayleigh signal

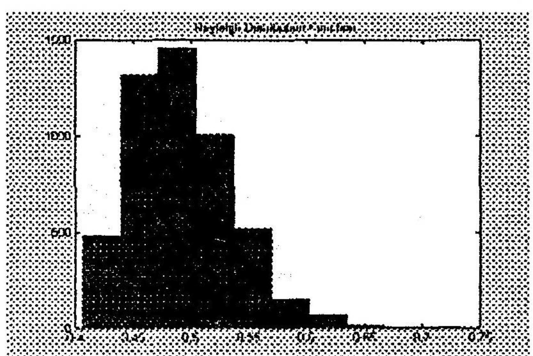
Figure 6: Rayleigh Distribution Function

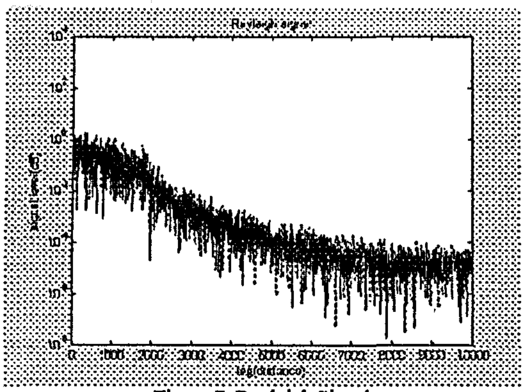

Figure 7: Rayleigh Signal

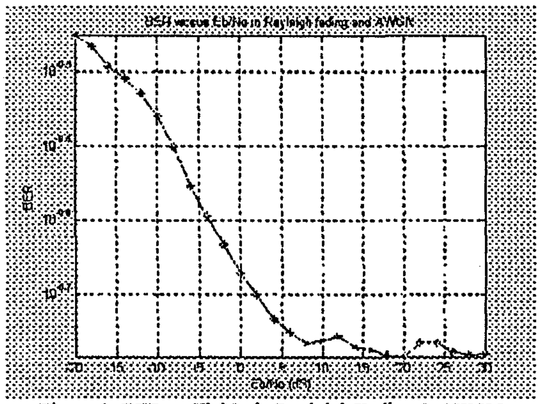

Figure 8: BER vs Eb/No in Rayleigh Fading & AWGN

The rayleigh fading channel is simulated where the transmitted data stream is multiplied by a Rayleigh fading envelope. It then adds WGN samples as before to obtain the desired Eb/No at the receiver.
The performance in terms of BER vs Eb/No is reported in the above, figure 8 in this figure, a remark must be done concerning the crossing of the Rayleigh BER curve below the AWGN BBER curve.

5. Conclusion and Future Works

5.1 Conclusion

OFDM signaling is proven to be effective way to combat the negative effects of fading and multipath by dividing the frequency selective fading channel into a number of flat fading sub channels corresponding to the OFDM sub carrier frequencies. When compared to single carrier systems, channel equalization is less complex, and sensitivity to channel estimation and frame synchronization errors can be reduced. However, OFDM systems are more sensitive to carrier frequency offsets than single carrier systems.

5.2 Future Development

OFDM has a promising future for use in wireless LAN networks and for fixed and mobile communications. Its use is likely to be significantly increased over the next 10 year, due to its high spectral efficiency and flexibility in spectrum allocation and modulation. OFDM is mostly suited to low mobility high data rate networks. At low user data rates, much of he adaptive techniques would not be suitable due to the high overhead of implementing such techniques. As a result, in multi-user applications at low data rates the overall efficiency of OFDM is much poorer with little advantage over CDMA techniques Mobile Networks of the future will shift away from low data rate voice applications to become primarily data terminals, striving for high data rates.

Most current multi-user OFDM systems use TDMA as a method for providing multiple accesses. However the greatest performance gains can be made by jointly allocating users based on frequency and time. Due to the overlapping nature of sub carriers in OFDM signals, allocating users different sub carriers in the reverse link creates problems in maintaining sub carrier orthogonality. Each mobile user will have a different propagation delay and Doppler spread, making compensation for these factors in the reverse link a non-trivial problem. It is possible that the most robust schemes will use blocks of OFDM signals, which are band pass filtered to help separate signals from different users.

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