Chapter 4

OFDM Transmission over Wideband Channel

4.1 The Time Dispersive Channel Model

☞**A time-dispersive channel can be characterized by its channel impulse response**

$$h(t) = \sum_{i=0}^{L-1} \alpha_i(t)\delta(t-\tau_i)$$

where

L **is the number of multipath components**

$\alpha_i(t)$ **is the path gain of path I**

τ_i **is the path delay of path i**

4.1 The Time Dispersive Channel Model

- **Each path gain $\alpha_i(t)$ is a complex random variable with uniformly distributed phases and Rayleigh distributed magnitude.**
- **The average power of each path decays exponentially.**

4.1 The Time Dispersive Channel Model

☞ **The mathematical model for the channel is**

$$\alpha_i = N(0, \frac{1}{2}\sigma_i^2) + j \cdot N(0, \frac{1}{2}\sigma_i^2)$$

$$\sigma_i^2 = \sigma_0^2 \, e^{-iT_s / T_{RMS}}$$

$$\sigma_0^2 = 1 - e^{-T_s / T_{RMS}}$$

where T_s **is the sampling period, and** T_{RMS} **is the root-mean- squared (RMS) delay spread.**

4.2 Effects of Time Dispersive Channels on OFDM

The phenomenon of multipath fading causes previous symbol to interfere with the latter symbol. This is known as the inter-symbol interference (ISI).

Let h_n **sequence be the discrete-time equivalent channel impulse response. The received signal is the convolution of the transmitted symbols and the discrete-time channel impulse response.**

4.3 Channel Estimation

(1) Time Domain Channel Estimation

(2) Frequency domain Channel Estimation

4.3.1 Time Domain Channel Estimation

☞**The received time domain signals are**

$$r_n = h_n \otimes x_n + w_n, \qquad n = 1 \ldots 64; \cdots\cdots\cdots(4.1)$$

h_n **is the channel impulse response.**

x_n **is the known symbol.**

w_n **is noise.**

4.3.1 Time Domain Channel Estimation

☞**The time domain convolution can be expressed as a matrix vector multiplication.**

$$\underline{\underline{X}} = \begin{bmatrix} x_1 & x_{64} & \cdots & \cdots & \cdots & x_{64-L+2} \\ x_2 & x_1 & \ddots & & & x_{64-L+3} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ x_{63} & x_{62} & \vdots & & \ddots & x_{64-L} \\ x_{64} & x_{63} & \vdots & & & x_{65-L} \end{bmatrix} \qquad \underline{h} = \begin{bmatrix} h_0 \\ h_1 \\ h_2 \\ \vdots \\ h_{L-1} \end{bmatrix}$$

☞**The parameter L defines the maximum length of the impulse response, L<64.**

4.3.1 Time Domain Channel Estimation

☞ **Then receive signal is expressed as**

$$\underline{r}_n = h_n \otimes x_n + w_n = \underline{\underline{X}}\,\underline{h} + \underline{w}$$

$$\begin{bmatrix} r_1 \\ r_2 \\ r_3 \\ r_4 \\ \vdots \\ r_{64} \end{bmatrix} = \begin{bmatrix} x_1 & x_{64} & \cdots & \cdots & \cdots & x_{64-L+2} \\ x_2 & x_1 & \ddots & & & x_{64-L+3} \\ \vdots & \vdots & \vdots & \ddots & & \vdots \\ x_{63} & x_{62} & \vdots & & \ddots & x_{64-L} \\ x_{64} & x_{63} & \vdots & & & x_{65-L} \end{bmatrix} \begin{bmatrix} h_0 \\ h_1 \\ h_2 \\ \vdots \\ h_{L-1} \end{bmatrix} + \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_4 \\ \vdots \\ w_{64} \end{bmatrix}$$

4.3.1 Time Domain Channel Estimation

☞**The Least Squared estimate for $\underline{h}$ is**

$$\underline{\hat{h}}_{LS} = (\underline{\underline{X}}^H \underline{\underline{X}})^{-1} \underline{\underline{X}}^H \underline{r}$$

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4.3.2 Frequency domain Channel Estimation

☞**We get (4.2) from (4.1) through FFT transform,**

$$R_k = X_k H_k + W_k \quad \ldots\ldots(4.2)$$

☞**If we have two repeat sequence,**

$$\underline{R} = \begin{bmatrix} R_{1,k} \\ R_{2,k} \end{bmatrix} = \begin{bmatrix} X_k \\ X_k \end{bmatrix} H_k + \begin{bmatrix} W_{1,k} \\ W_{2,k} \end{bmatrix}$$

4.3.2 Frequency domain Channel Estimation

☞**The LS estimate for each** H_k **is**

$$\hat{H}_k = \frac{1}{2}(X^H{}_k X_k)^{-1} X^H{}_k (R_{1,k} + R_{1,k})$$

$$= \frac{1}{2|X_k|^2} X^H{}_k (R_{1,k} + R_{2.k})$$

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4.4 Comparisons of Time- and Frequency-Domain Equalization

Time-Domain Equalization	Frequency-Domain Equalization
Convolution $\hat{h}_n \otimes r_n$	**One-tap multiplication** $\hat{H}^*_k \cdot R_k$
High Complexity when L is lagre	**High complexity when L is small**
No FFT Required	**FFT Required**

References

- **[1] L. Hanzo, W. Webb and T. Keller,** ***Single- and multi-carrier quadrature amplitude modulation – Principles and applications for personal communications, WLANs and broadcasting*****, John Wiley & Sons, Ltd, 2000.**
- **[2] Mark Engels,** ***Wireless Ofdm Systems: How to Make Them Work?*** **Kluwer Academic Publishers.**