M1 課題レポート 第3回

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Technical Report for M1 Labwork 3rd

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Abstract In this third C workshop, we use C language to simulate fading in wireless communication due to delay and multi-path of transmission. In this workshop, we mainly simulate two fading channel: Rayleigh fading channel and frequency selective fading channel. First, we introduce the backgroud knowledege of these two fading channel. Next, we state the whole system desgin and simulation condition. Finally, we can see simulation BER performance of these two fading channel

1. Introduction

Fading is attenuation of a signal in wireless communication caused by several factors. We can consider fading as a random process, which affects amplitude and phase of received signal. In this workshop, we mainly concentrate on two types of fading channel: Rayleigh fading channel and frequency selective fading channel. The full name of acronyms is summed in Table 1.

1.1 Rayleigh Fading Channel

Rayleigh fading is due to overlapping of multiple received radio waves at receiver. Power of received signal will stochastically fluctuates depending on distance to transmitter, time and mobility of receiver. The distribution of Rayleigh fading channel obeys joint of two independent and identically distributed Gaussian variables [1]:

$$p(x,y) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \tag{1}$$

The amplitude of received signal obeys Rayleigh distribution:

$$p(r) = \frac{r}{\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right) \tag{2}$$

And the phase of received signal obeys uniform distribution:

$$p(\theta) = \frac{1}{2\pi} \tag{3}$$

The received signal $r(t)$ can be represented as follow:

$$r(t) = h(t,\tau) * s(t) + n(t) \tag{4}$$

$h(t,\tau)$ in the model is impulse response of Rayleigh Fading Channel with D paths, and τ is delay of each path, which is considered much smaller than one symbol time and can be ignored. Finally, the Rayleigh Fading Channel model can be written in the following form:

$$r(t) = \sum_{d=0}^{D-1} h_d(t)s(t) + n(t) \tag{5}$$

Rayleigh fading is also called flat fading because its frequency response keeps flat in the bandwidth of transmit signal.

Table 1 ACRONYMS AND FULL MEANING

Acronyms	**Full Form**
MLE	Maximum Likelihood Estimator
QPSK	Quadrature Phase Shift Keying
DQPSK	Differential Quadrature Phase Shift Keying
BER	Bit Error Rate
SNR	Signal Noise Ratio
AWGN	Additive White Gaussian Noise
PDF	Probability Distribution Function
ISI	Inter Symbol Interference

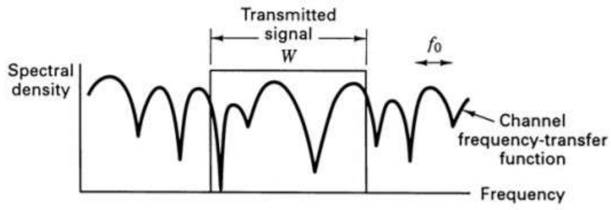

Fig. 1 Impulse Response of Frequency Selective Fading Channel

1. 2 Frequency Selective Fading Channel

Another important fading is frequency selective fading channel, which is also caused by overlapping of several delayed waves in different propagation paths. Compare to Rayleigh fading, the delay of each path in this fading exceeds one symbol time and will cause specific frequency attenuation in the bandwidth of transmission signal. The impulse response of frequency selective fading is shown in Fig. 1. If we suppose only two paths in channel, we can build channel model as follow:

$$r(i) = h_0 s(i) + \underbrace{h_1 s(i-1)}_{\text{ISI}} + n(i) \tag{6}$$

h_0 and h_1 are channel impulse response of each path.

2. Simulation Desgin

In this chapter we will introduce how to realize above two fading channel in C program and simulate BER performance with different Doppler shift.

2. 1 Design of Rayleigh Fading Channel Simulation

Rayleigh fading channel can be represented in below form:

$$h(t) = \sum_{n=0}^{N-1} A_n \exp[j(2\pi f_D \cos\theta_n + \phi_n)] \tag{7}$$

An is amplitude of impulse response which obeys 0 mean Gaussian distribution. $f_D = \frac{v}{\lambda} = \frac{vf_c}{c}$ is Doppler frequency which affects the rate of channel change over time. ϕ_n is initial phase which obeys uniform distribution. N is number of waves, and if N is large enough, according to Central Limit Theorem, $h(t)$ becomes 2 dimensional Gaussian distribution [2]. The theoretical BER of Rayleigh fading channel is [3]:

$$P_e(x) = \frac{1}{2}\left(1 - \sqrt{\frac{x}{x+1}}\right) \tag{8}$$

x is ber which is not in dB form.

To achieve best BER performance, receiver need to estimate channel state information to counteract amplitude attenuation and phase shift of receiving signal. However, even if we suppose the estimated signal is perfect, Rayleigh

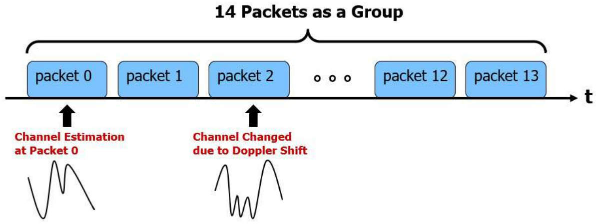

Fig. 2 Illustration of Rayleigh Fading Channel

channel will change over time which is shown in Figure. 2. Thus, if Doppler shift is existed, the BER of the receiving end cannot be close to the theoretical value according to (7).

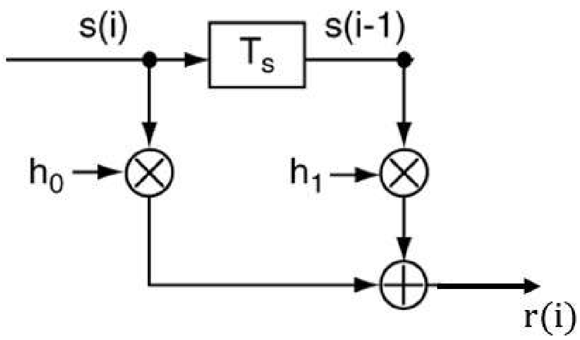

Fig. 3 Illustration of Frequency Selective Fading Channel

2. 2 Design of Frequency Selective Fading Channel Simulation

The generation process of frequency selective channel is illustrated in Fig. 3. Both h_0 and h_1 are generated as Rayleigh fading and each power is $\frac{1}{2}$ to let the power of the received signal be unit 1 [4].

Table 2 SIMULATION CONDITIONS

ITEMS	CONDITIONS
Moduation Method	QPSK/DQPSK
Transmission Bits	128
Group Size	14
Channel	Rayleigh Fading/Selective Fading Channel
Detection	Noncoherent/Coherent Detection
Number of Trials	10^4
Decision Method	MLE
Channel Estimation	$\hat{h} = h$
Rayleigh Waves	8
SNR Range	0-30 dB

2. 3 Simulation Result

The simulation codition is listed in Table 2. BER performance of coherent demodulation in different Doppler shift in Rayleigh fading channel is shown in Fig. 4. We can see that QPSK and coherent demodualtion is not able to handle Rayleigh fading channel with Doppler shift, that the BER performance when f_d is 1000 Hz is unacceptable. Then Fig. 5 shows theoretical and simulation BER curve of coherent demodulation and non-coherent demodulation without Doppler shift in Rayleigh fading channel, which we can see the simulation curve is quite consistent with the theoretical curve, and BER performance of coherent demodulation is 3 dB better than non-coherent demodulation. Fig. 6 shows BER performance of noncoherent demodulation in different Doppler shift. We can see that as the Doppler shift increases, the performance of BER gets worse.

Fig. 7 shows BER performance when Doppler shift is 0 Hz, 100 Hz and 1000 Hz in frequency selective channel. Due to ISI, system BER performance is worse than flat fading channel.

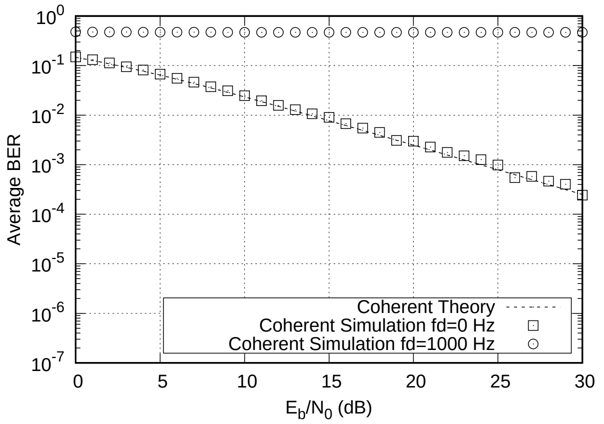

Fig. 4 Coherent Demodulation BER with and without Phase Shift in Rayleigh Fading Channel

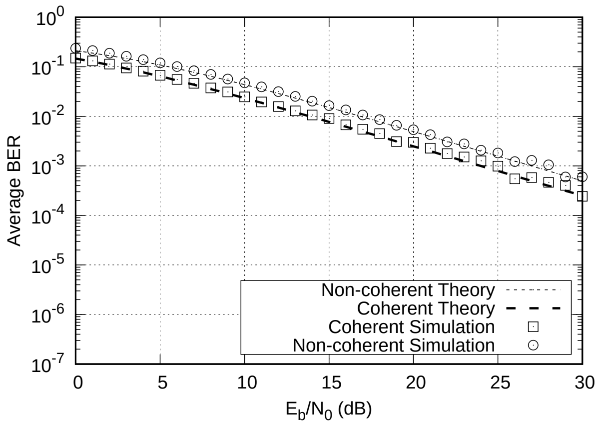

Fig. 5 Theoretic and Simulation BER without Doppler Shift in Rayleigh Fading Channel

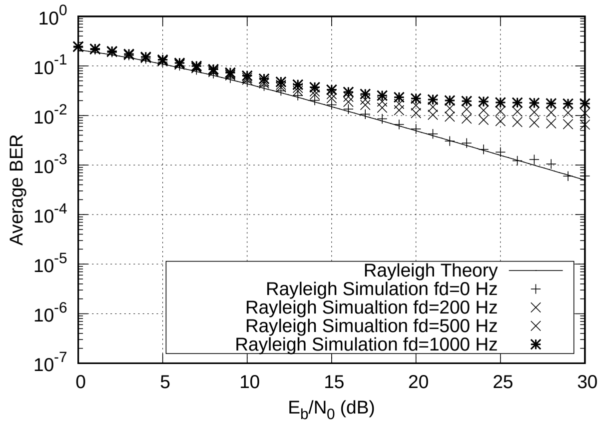

Fig. 6 QPSK and Noncoherent Demodulation BER with Different Doppler Shift in Rayleigh Fading Channel

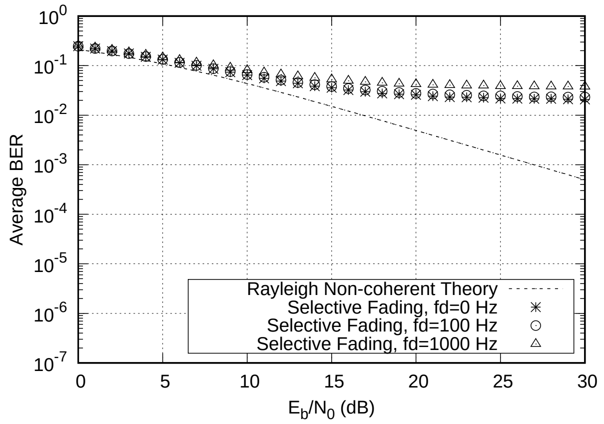

Fig. 7 QPSK and Noncoherent Demodulation BER with Different Doppler Shift in Selective Fading Channel

3. Conclusion

In this workshop, we simulate BER performance in Rayleigh fading channel and frequency selective fading channel respectively. In summary of simualtion result, coherent demodulation performs better than noncoherent demodulation when there isn't any Doppler shift. However, BER performance of QPSK and coherent demodulation become unacceptable when Doppler shift appear. And in nonconherent demodulation, BER performance become worse as Doppler shift increases. In frequency selective fading channel, BER performance become much worse due to ISI. Thus, we need to deal with the special receiving method of this channel to achieve acceptable BER.

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