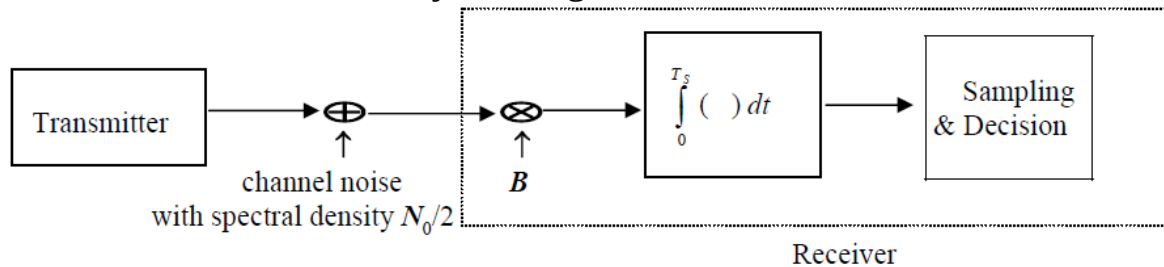


EE3101 Communication Engineering

Tutorial 9

- (1) A 1.544Mb/s random binary signal is converted into a 4-level NRZ signal. The output levels are: $-3.4A$, $-A$, A and $3.4A$. Consider the receiver as shown below is used for signal detection. Assume that (i) the channel is AWGN with double-sided power spectral density of $N_0/2$; (ii) perfect timing is used at the receiver; and (iii) the decision levels are set at the middle of the two adjacent signal levels.



- (a) What is the symbol duration T_s ;
- (b) What are the four output signal levels at the integrator output?
- (c) Determine the noise power σ^2 at the integrator output in terms of N_0 , B and T_s .
- (d) Determine the 3 threshold levels and then derive the symbol error probability P_S in terms of A , T_s and N_0 .
- (e) Express the symbol error in terms of $\frac{E_b}{N_0}$.
- (2) John joins the Research & Development (R&D) Department of an Electronic Company. His first task is to upgrade the current 100Mb/s QPSK wireless product to 300Mb/s and with similar error performance. The current product operates in ISM frequency band with transmission power $P=10\text{mW}$. John checks that the hardware and software of the system are capable to work at 300Mb/s. His proposal is: Just increase the bit rate to 300Mb/s with the same QPSK modulation but increase the transmission power to $3P$ (i.e. 30mW).
- (i) What is the purpose of increasing the transmission power to $3P$ in John's proposal?
- (ii) Comment on John's proposal.

(3) Consider a BPSK system where “0” and “1” are represented by $s_0(t) = E\sqrt{\frac{2}{T}}\cos(\omega_c t)$ and $s_1(t) = E\sqrt{\frac{2}{T}}\cos(\omega_c t + \theta)$ {where $\theta \neq 0$ } respectively. The system is operated under an AWGN channel with double-sided power spectral density of $N_0/2$. Coherent detection with a reference signal of $\psi(t) = \sqrt{\frac{2}{T}}\cos(\omega_c t)$ is used at the receiver, as shown in Fig.Q3.

- (a) Determine the average signal levels $E[x(T)|s_0]$ and $E[x(T)|s_1]$ at the integrator output. Assume that all high frequency components involving $2\omega_c$ can be ignored in the demodulation process.
- (b) Assume that the optimum threshold h is set at the middle of the two adjacent signal levels, i.e. $h = (E[x(T)|s_0] + E[x(T)|s_1])/2$, show that

$$h = \frac{E}{2}[1 + \cos(\theta)],$$

and hence show that the bit error probability $P_B = Q\left[\sqrt{\frac{E_b}{2N_0}}(1 - \cos\theta)\right]$

where E_b is the average bit energy.

- (c) Determine the value of θ for optimum (i.e. minimum) P_B .

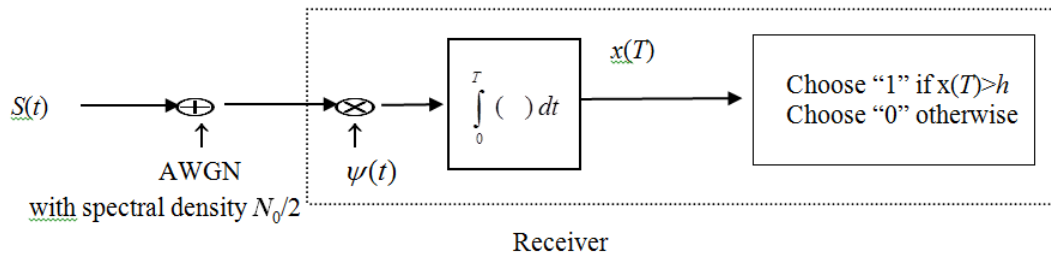


Fig.Q3 The receiver of a BPSK Receiver with coherent detection

$$\left\{ \begin{aligned} \text{Note: } Q(x) &= \frac{1}{\sqrt{2\pi}} \int_x^\infty \exp\left(-\frac{u^2}{2}\right) du, \quad \Rightarrow \quad \frac{dQ(x)}{dx} = -\frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right) \\ &\Rightarrow \frac{dQ(x)}{dy} = \frac{dQ(x)}{dx} \frac{dx}{dy} \end{aligned} \right\}$$

- (4) A QPSK wireless line-of-sight link is established between two buildings and a coherent demodulator is used at the receiver. The channel is modelled by an Additive White Gaussian Noise $n(t)$ with double-sided power spectral density of $N_0/2$. The received signal $r(t)$ can be expressed as:

$$r(t) = A \sqrt{\frac{2}{T}} [I(t) \cos(\omega_c t) - Q(t) \sin(\omega_c t)] + n(t)$$

where $I(t), Q(t) \in \{\pm 1\}$, A is a constant and T is the bit duration.

Assume that (i) the received signal power is much higher than the noise power, (ii) a small phase offset θ ($\theta \ll \frac{\pi}{2}$) exists between the receiver's local carrier and the received signal, i.e. the reference signals for I channel and Q channel are $\sqrt{\frac{2}{T}} \cos(\omega_c t + \theta)$ and $\sqrt{\frac{2}{T}} \sin(\omega_c t + \theta)$ respectively (where ω_c is the carrier frequency), and (iii) the decision threshold values remain at zero volt, show that symbol error probability can be approximated as:

$$P_S \cong Q\left[\sqrt{\frac{2E_b}{N_0}} (\cos\theta + \sin\theta)\right] + Q\left[\sqrt{\frac{2E_b}{N_0}} (\cos\theta - \sin\theta)\right]$$

where E_b is the average bit energy at the receiver input.