ELEC3026 MODEM: Brief Notes

Coherent and Non-coherent Receivers

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Coherent Receiver

(a) Carrier recovery for demodulation

- Receiver signal $\hat{S}(t) = A\cos\left(\omega_c t + \varphi\right) + N(t)$
- Local carrier $\cos\left(\omega_c t + \bar{\varphi}\right)$
- Carrier recovery (e.g. phase lock loop) circuit

$$\Delta\varphi = \varphi - \bar{\varphi} \rightarrow 0 \quad \text{i.e.} \quad \bar{\varphi} \rightarrow \varphi$$

- Demodulation leads to recovered baseband signal

$$Y(t) = X(t+\tau) + N(t)$$

where $X(t)$ is transmitted baseband signal

(b) Timing recovery for sampling

- Align receiver clock with transmitter clock, so that sampling $\Rightarrow$ no ISI

$$Y_k = X_k + N_k$$

where X_k are transmitted symbols, and N_K noise samples

Non-coherent Receiver

(a) No carrier recovery for demodulation

- Receiver signal $\hat{S}(t) = A\cos\left(\omega_c t + \varphi\right) + N(t)$
- Local carrier $\cos\left(\omega_c t + \bar{\varphi}\right)$
- No carrier recovery,

$$\phi = \Delta\varphi = \varphi - \bar{\varphi} \neq 0 \quad \text{i.e.} \quad \bar{\varphi} \neq \varphi$$

- Demodulation leads to recovered baseband signal

$$Y(t) = X(t+\tau)e^{j\phi} + N(t)$$

(b) Timing recovery for sampling

- Align receiver clock with transmitter clock, sampling results in

$$Y_k = X_k e^{j\phi} + N_k$$

Could not recover transmitted symbols properly from Y_k !

Differential Detection

(a) **Differential encoding** for transmission

– Symbols $\{C_k\} \Rightarrow \{X_k\}$ for transmission

$$X_k = C_k \cdot X_{k-1}$$

– As $X_k \cdot X_{k-1}^* = C_k \cdot \big(X_{k-1} \cdot X_{k-1}^*\big)$,

$$C_k = \frac{X_k \cdot X_{k-1}^*}{|X_{k-1}|^2} \tag{1}$$

(b) **Non-coherent** detection

– Receiver samples
$$Y_k = X_k \cdot |H| \cdot e^{j\phi} + N_k$$

$|H|$: magnitude of combined channel tap, $\phi \neq 0$: unknown phase

– Differential decoding

$$\hat{C}_k = \frac{Y_k \cdot Y_{k-1}^*}{|Y_{k-1}|^2} \tag{2}$$

Differential Detection (derivation)

$$\begin{aligned} Y_k \cdot Y_{k-1}^* &= \left(X_k \cdot |H| \cdot e^{j\phi} + N_k\right) \cdot \left(X_{k-1}^* \cdot |H| \cdot e^{-j\phi} + N_{k-1}^*\right) \\ &= X_k \cdot X_{k-1}^* \cdot |H|^2 \cdot e^{j(\phi-\phi)} \\ &\quad + N_k \cdot N_{k-1}^* + X_k \cdot |H| \cdot e^{j\phi} \cdot N_{k-1}^* + N_k \cdot X_{k-1}^* \cdot |H| \cdot e^{-j\phi} \end{aligned}$$

$$\begin{aligned} |Y_{k-1}|^2 &= X_{k-1} \cdot X_{k-1}^* \cdot |H|^2 + N_{k-1} \cdot N_{k-1}^* \\ &\quad + X_{k-1} \cdot |H| \cdot e^{j\phi} \cdot N_{k-1}^* + N_{k-1} \cdot X_{k-1}^* \cdot |H| \cdot e^{-j\phi} \end{aligned}$$

When noise N_k is very small

$$Y_k \cdot Y_{k-1}^* \approx X_k \cdot X_{k-1}^* \cdot |H|^2 \quad \text{and} \quad |Y_{k-1}|^2 \approx |X_{k-1}|^2 \cdot |H|^2$$

- Thus,

$$\hat{C}_k = \frac{Y_k \cdot Y_{k-1}^*}{|Y_{k-1}|^2} \approx C_k + \bar{N}_k$$

  where power of enhanced noise $\bar{N}_k$ is **larger** than that of N_k

- Note that influence of channel phase ϕ has been removed

Comparison

- Coherent detection
  - Require expensive and complex carrier recovery circuit
  - Better bit error rate of detection

$$\hat{X}_k = X_k + N_k$$

- Non-coherent detection
  - Do not require expensive and complex carrier recovery circuit
  - Poorer bit error rate of detection

$$\hat{C}_k = C_k + \bar{N}_k$$

- Differential systems have important advantages and are widely used in practice