Review:

- CSIR + CSIT + power adaptation

water-filling

$$C = \int_{\gamma_0}^{+\infty} B \log\left(\frac{\gamma}{\gamma_0}\right) f(\gamma)\, d\gamma$$

28 十四 Monday

$$\gamma = \frac{g\bar{P}}{N_0 B}$$

- CSIR + CSIT + Channel Inversion

$$P = \frac{\sigma}{\gamma} \cdot \bar{P} = \frac{\sigma \cdot N_0 B}{g}$$

29 十五 Tuesday

$$C = B \cdot \log_2\left(1 + \frac{1}{E[1/\gamma]}\right)$$

30 十六 Wednesday

△ CSIR & CSIT

Outage Capacity, Truncated Channel Inversion

$$\frac{p(\gamma)}{\bar{P}} = \begin{cases} \frac{\sigma}{\gamma}, & \text{if } \gamma \geq \gamma_0 \\ 0, & \text{if } \gamma < \gamma_0 \end{cases}$$

Outage Capacity:

$$C = B \cdot \log_2(1+\sigma) \cdot P_r(\gamma \geq \gamma_0)$$

$$E[p(\gamma)] = \int_{\gamma_0}^{+\infty} p(\gamma) \cdot f(\gamma)\, d\gamma = \bar{P}$$

$$\Rightarrow \sigma = 1 \Big/ \int_{\gamma_0}^{+\infty} \frac{1}{\gamma} \cdot f(\gamma) d\gamma$$

$$= 1 / E_{\gamma_0}[1/\gamma]$$

$$\Rightarrow C = B \log_2\left(1 + \frac{1}{E_{\gamma_0}[1/\gamma]}\right) \cdot P_r(\gamma \geq \gamma_0)$$

maximum outage capacity:

$$C = \max_{\gamma_0} B \cdot \log_2\left(1 + \frac{1}{E_{\gamma_0}[1/\gamma]}\right) \cdot P_r(\gamma \geq \gamma_0)$$

Digital Modulation and Detection

△ Digital Modulation

Mapping from info. bits to analog signals

message

$M = \{m_1, m_2, \cdots, m_M\}$

$K = \log_2 M$

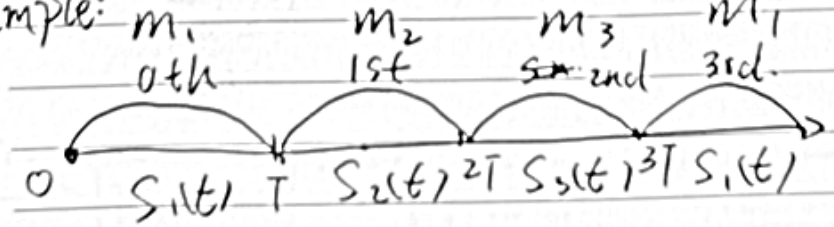
$\Downarrow$

$m_i = \{b_1, b_2, \cdots, b_K\}$ $\quad s_i(t) \in \{s_1(t), s_2(t), \cdots s_M(t)\}$

→ Transmitter →

$m_i \rightarrow s_i(t) \quad i = 1, \cdots, M$

Example:



Let T be the signal duration.

$s(t) = s_1(t) + s_2(t-T) + s_3(t-2T) + s_1(t-3T)$

Suppose message $m(k) \in \{1, \cdots, m\}$ is transmitted in the k-th period. $\Rightarrow s_{m(k)}(t-kT)$

$$s(t) = \sum_{k=0}^{+\infty} s_{m(k)}(t-kT)$$

Energy of $s_i(t)$: $E_{si} = \int_0^T s_i^2(t)\,dt$

△ Geometric Representation of Signals

Orthonormal basis functions

$$\phi = \{\phi_1(t), \phi_2(t), \cdots, \phi_N(t)\} \quad t \in [0, T]$$

$$\langle \phi_i(t), \phi_j(t) \rangle = \int_0^T \phi_i(t)\cdot\phi_j(t)\,dt = \begin{cases} 1, & i=j \\ 0, & i \neq j \end{cases}$$

e.g.: $\begin{cases} \phi_1(t) = \sqrt{\frac{2}{T}}\cos(2\pi f_c t) \\ \phi_2(t) = \sqrt{\frac{2}{T}}\sin(2\pi f_c t) \end{cases}$

$$s_i(t) = \sum_{j=1}^{N} s_{ij}\cdot\phi_j(t), \quad 0 \le t < T$$

$$\int_0^T s_i(t)\cdot\phi_j(t)\,dt = s_{ij}$$

$= \langle s_i(t), \phi_j(t) \rangle$

Given ϕ, signals $\{s_i(t)\}$ can be represented by $(s_{i1}, \cdots s_{iN})$ $(s_{m1}, \cdots s_{mN})$

$s_i(t) \rightarrow (s_{i1}, s_{i2}, \cdots s_{iN}) \triangleq \vec{s_i}$ $i = 1, \cdots, M$

signal constellation point: a point in N-dimensional space.

signal constellation: $\{\vec{s_1}, \vec{s_2} \cdots, \vec{s_M}\}$

14 日二

Thursday 星期四

signal space

QPSK / QAM

SUSTech

1

~~E.g.~~ $S_i(t) = S_{i1}\phi_1(t) + S_{i2}\phi_2(t)$

$= S_{i1}\sqrt{\frac{2}{T}}\cos 2\pi f_c t + S_{i2}\sqrt{\frac{2}{T}}\sin 2\pi f_c t.$

QAM Signals:

~~QPSK: $(S_{i1}, S_{i2}) = \{(1,1), (1,-1), (-1,1), (-1,-1)\}$~~

QPSK: (S_{11}, S_{12}) (S_{21}, S_{22}) (S_{31}, S_{32}) (S_{41}, S_{42})

$(1 \quad 1)$ $(1 \quad -1)$ $(-1 \quad 1)$ $(-1, -1)$

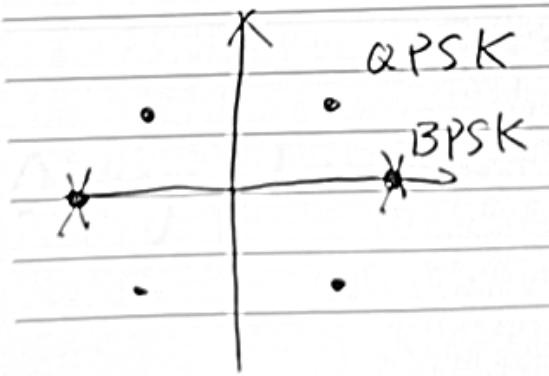
BPSK: $S_1(t) = A\cos(2\pi f_c t)$ "1"

$S_2(t) = -A\cos(2\pi f_c t)$ "0"

$\phi = \{\sqrt{\frac{2}{T}}\cos 2\pi f_c t\}$ $N=1$

$S_{11} = \int_0^T S_1(t)\cdot\sqrt{\frac{2}{T}}\cos 2\pi f_c t\,dt = A\sqrt{\frac{T}{2}}$

$S_{21} = \int_0^T S_2(t)\cdot\sqrt{\frac{2}{T}}\cos 2\pi f_c t\,dt = -A\sqrt{\frac{T}{2}}$



$\vec{S_i} = (S_{i1}, S_{i2}, \cdots, S_{iN})$

Length: $\|\vec{S_i}\| = \sqrt{\sum_{j=1}^{N} S_{ij}^2}$

distance between $\vec{S_i}$ and $\vec{S_k}$

$$\|\vec{S_i} - \vec{S_k}\| = \sqrt{\sum_{j=1}^{N} (S_{ij} - S_{kj})^2}$$

$$= \sqrt{\int_0^T [S_i(t) - S_j(t)]^2 dt}$$

inner product

$$\langle S_i(t), S_k(t) \rangle \triangleq \int_0^T S_i(t) \cdot S_k(t) dt$$

$$= \langle \vec{S_i}, \vec{S_k} \rangle$$

$$= \sum_{j=1}^{N} S_{ij} S_{kj}$$

Orthogonal : inner product = 0

△ AWGN Channel. (move to Rx part)

$$r(t) = s(t) + n(t)$$

* Flat Fading Channel.

$$r(t) = h \cdot s(t) + n(t)$$

$$\downarrow$$

$$\frac{r(t)}{h} = s(t) + \frac{n(t)}{h}$$ equivalent AWGN