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 / 星期一

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

- CSIR + CSIT + Channel Inversion

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

29 十五
Tuesday / 星期二

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

30 十六
Wednesday / 星期三

△ CSIR & CSIT

Outage Capacity, Truncated Channel Inversion

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

Outage Capacity:

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

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

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

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

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

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

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

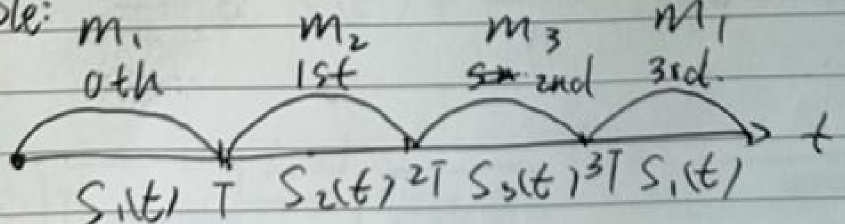
$K=\log_2 M$

⇓

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

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

Example:



Let T be the signal duration.

SUSTech

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

Suppose message $m(k)$ ~~is~~ $\in \{1, \cdots, m\}$ 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 $s_i(t)$: $E_{s_i} = \int_0^T s_i^2(t)\,dt$

△ Geometric Representation of Signals.

Orthonormal basis functions

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

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

$$\text{E.g.:} \left\{ \begin{array}{l} \phi_1(t) = \sqrt{\frac{2}{T}} \cos(2\pi f_c t) \\ \phi_2(t) = \sqrt{\frac{2}{T}} \sin(2\pi f_c t) \end{array} \right\}$$

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

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

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

Given ϕ, signals $\{s_i(t)\}$ can be represented by $(s_{11}, \cdots s_{1N})$ $\vdots$ $(s_{M1}, \cdots s_{MN})$

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

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

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

signal space

QPSK / QAM

~~飞等~~ $s_i(t) = s_{i1}\phi_1(t) + s_{i2}\phi_2(t)$

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

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})

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

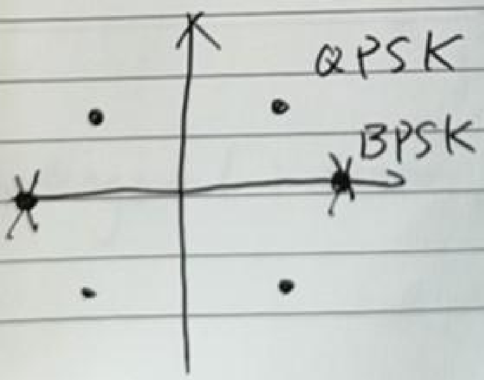
BPSK: $s_1(t) = \alpha\cos(2\pi f_c t)$ "1"

$s_2(t) = -\alpha\cos(2\pi f_c t)$ "0"

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

$$s_{11} = \int_0^T s_1(t)\cdot\sqrt{\frac{2}{T}}\cos 2\pi f_c t\,dt = \alpha\sqrt{\frac{T}{2}}$$

$$s_{21} = \int_0^T s_2(t)\cdot\sqrt{\frac{2}{T}}\cos 2\pi f_c t\,dt = -\alpha\sqrt{\frac{T}{2}}$$



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

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 ~~p~~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.

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

$$\Downarrow$$

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

$$\xrightarrow{m_i} \boxed{\text{Transmitter}} \xrightarrow{s_i(t)} \boxed{\text{AWGN}} \xrightarrow{r(t)} \boxed{\text{Receiver}} \xrightarrow{\hat{m}}$$