ELEN90051 Advanced Communication Systems

2018 Semester 1 Tutorial 3

Modulation

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26/03/2018

Instructions:

Answer all tutorial questions. Do not use any solution material that you happen to have, thus simulating a genuine exam environment.

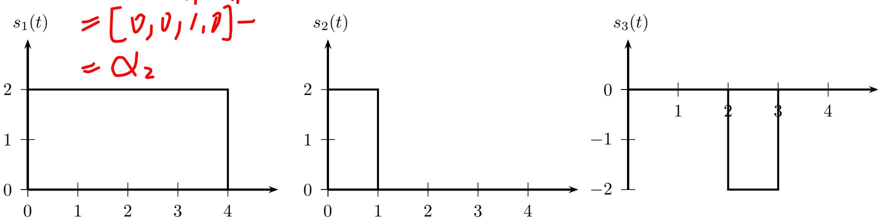
$e_1 = \alpha_1 = [1,0,0,0]^T$

$e_2 = \alpha_2 - \frac{(\alpha_2, e_1)}{\|e_1\|^2} \cdot e_1$

$= [0,0,1,0] -$

$= \alpha_2$

1



(a) What is the dimension of the signal space spanned by $\{s_1(t), s_2(t), s_3(t)\}$? I guess it's 3

(b) Sketch a set of orthonormal basis functions for the signal space, clearly labelling the axes and points.

(c) Use the basis functions to represent the signals as vectors $\mathbf{s}_1$, $\mathbf{s}_2$, and $\mathbf{s}_3$.

2 Consider the signal waveforms defined by

$$s_1(t) = \begin{cases} 2 & 0 \le t \le 1 \\ -1 & 1 \le t \le 4 \\ 0 & \text{otherwise} \end{cases}$$ $[2,-1,-1,-1] = \alpha_2$

$$s_2(t) = \begin{cases} -2 & 0 \le t \le 1 \\ 1 & 1 \le t \le 3 \\ 0 & \text{otherwise} \end{cases}$$ $[-2,1,1,0] = \alpha_1$

$$s_3(t) = \begin{cases} -1 & 0 \le t \le 1 \\ 2 & 1 \le t \le 3 \\ -1 & 3 \le t \le 4 \\ 0 & \text{otherwise} \end{cases}$$ $[-1,2,2,-1] = \alpha_3$

(a) Determine a set of orthonormal basis functions for $s_1(t)$, $s_2(t)$, $s_3(t)$ and the corresponding vector representations.

$e_1 = [-2,1,1,0]$

$\Rightarrow e_2 = [0,0,0,-1]$

$e_3 = [1,1,1,0]$

$e_1 = \alpha_1$

$e_2 = \alpha_2 - \frac{(e_1, \alpha_1)}{\|e_1\|^2} e_1 = [2,-1,-1,-1]$

$\Rightarrow [0,0,0,-1] + \alpha_1$

$d_{min} = \| [1,1,1,-1] \|^2 = \sqrt{4} = 2$

$e_3 = [-1,2,2,-1] - \frac{6}{6} e_1 = [1,1,1,-1] - \frac{1}{1}[0,0,0,-1] = [1,1,1,0]$

(b) What is the minimum distance between any pair of vectors in the set $\{\mathbf{s}_k\}_{k=1}^{3}$?

(c) Why is it important to normalize the basis functions?

To make the energy to be 1.

3 A set of M-PAM signals have the form

Modulation 是按照 basis 的个数来分类

$$s_m(t) = \begin{cases} s_m \phi(t) & 0 < t \le T \\ 0 & \text{otherwise} \end{cases}$$

where $s_m = \sqrt{\mathcal{E}_g} A_m, \; m = 1, \ldots, M.$

$-2A_1\sqrt{E_g} = (M-1)d$

$A_1 = \frac{(M-1)d}{2\sqrt{E_g}}$

(a) Show with the aid of a diagram that

$A_1\sqrt{E_g}$ $\quad A_m = \frac{(M-1)d}{2\sqrt{E_g}} + (m-1)A_m\sqrt{E_g}$

$$A_m = (2m - 1 - M)\frac{d}{2\sqrt{\mathcal{E}_g}}, \quad m = 1, \ldots, M,$$

when $\phi(t)$ has unit norm and d is the distance between adjacent signals.

(b) Calculate the average energy of the modulation scheme when $d = 2\sqrt{\mathcal{E}_g}$ and $M = 4$. What assumptions are made regarding the signals?

symmetrical

$\mathcal{E} = \frac{1}{4}\sum_{i=1}^{4} s_i^2 = 5E_g$

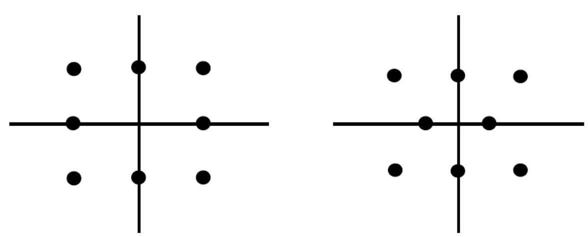
$-3\sqrt{E_g} \quad -\sqrt{E_g} \quad \sqrt{E_g} \quad 3\sqrt{E_g}$

4 Recall that in M-ary FSK, the signal waveforms can be written as follows for $m = 1, \ldots, M$:

$$s_m(t) = \begin{cases} \sqrt{\frac{2\mathcal{E}}{T}} \cos(2\pi f_c t + 2\pi m \Delta f t) & 0 < t \le T \\ 0 & \text{otherwise} \end{cases}$$

What is the minimum frequency separation for the waveforms to be orthogonal? $\frac{1}{2T}$

5 Consider the two 8-point QAM signal constellations shown below. The minimum distance between adjacent points is $2\sqrt{\mathcal{E}_g}$.



EASY

(a) What is the average transmitted power for each constellation assuming that the signal points are equally probable?

(b) Which constellation is more power efficient?

End of Questions