Laboratory Lesson 1

Digital Communications (EITG05)

Lund University
Department of Electrical and Information Technology

Signal alternatives, bit rate, and bandwidth

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Contents

1 INTRODUCTION

The purpose of this laboratory lesson is to give an increased understanding of commonly used digital communication methods. Important concepts studied here are bit rate versus bandwidth for various communication methods.

2 HOME PROBLEMS

(To be solved at home **before** this laboratory lesson.)

1. Read this laboratory instruction carefully, such that you are well aware of what you are expected to do during this laboratory lesson.
2. Calculate the bandwidth, defined as the one-sided width of the mainlobe, if the bit rate is 9600 bps, and if equiprobable M-ary PAM signal alternatives are used. Assume that the possible amplitudes are ± 1, ± 3, $\pm 5, \ldots \pm (M-1)$, and that the pulse $g(t)$ shown below is used. Furthermore, assume that:

   i) $M = 2$.   ii) $M = 256$.

   g(t)

   A

   $T_s/4$ $T_s/2$ t
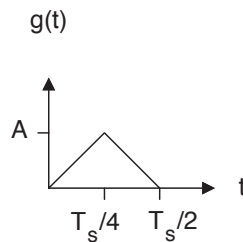
3. Assume bandpass M-ary PAM with carrier frequency $f_c = 2$ [GHz], and the $g_{rc}(t)$ pulse with duration $T = 0.8T_s = 10\ \mu s$. Calculate bit rates, and W_{lobe} for the cases $M = 2$, and $M = 1024$.
   How much of the signal power $\bar{P}$ is contained within the mainlobe?
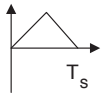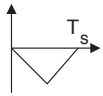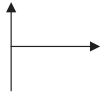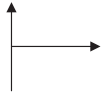   Is it here better to use $M = 1024$ than $M = 2$?
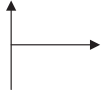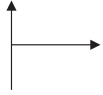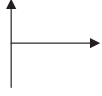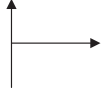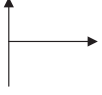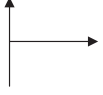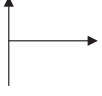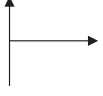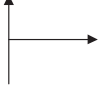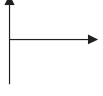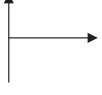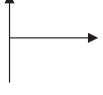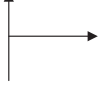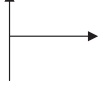
3 LABORATORY EXERCISE A: Signal constellations

Part A1: Binary signal constellations

Execute the file **binary.m**

Two figures are shown on the screen, each containing four different binary signal sequences. Each sequence has the structure $s_0(t)$, $s_1(t)$, $s_0(t)$, $s_1(t)$, ...

Classify each sequence by writing an "X" in appropriate places in the table below.

Sequence	$s_0(t)$	$s_1(t)$	PAM	PSK	FSK	QAM	PPM	PWM	Ortho-gonal	Anti-podal	On-Off
Ex			X							X	
1											
2											
3											
4											
5											
6											
7											
8											

Part A2: 4-ary signal constellations

Execute the file **four.m**

Two figures are shown on the screen, each containing four different signal sequences. Each sequence has the structure $s_0(t)$, $s_1(t)$, $s_2(t)$, $s_3(t)$, $s_0(t)$, $s_1(t)$, $s_2(t)$, $s_3(t)$, ...

Classify each sequence by writing an "X" in appropriate places in the table below.

Sequence	PAM	PSK	FSK	QAM	PPM	PWM	Orthogonal
1							
2							
3							
4							
5							
6							
7							
8							

Note! The laboratory assistent must check your answers before continuing with Laboratory exercise B.

4   LABORATORY EXERCISE B:
   The distribution of signal power in the frequency domain for bandpass M-ary PAM signals

Here we study properties in the frequency domain for bandpass M-ary PAM signals. It is assumed that $M = 2^k$, equiprobable signal alternatives are used, and that the average amplitude equals zero (see Subsection 2.4.1.1 on page 32 in the compendium). Furthermore, the bit rate is assumed to be $R_b = 19200$ **bps**.

In Parts B1 and B2 below, the carrier frequency is $f_c = 10/T_s$.

A bandpass PAM signal alternative can be written as $s_\ell(t) = A_\ell g(t) \cos(\omega_c t)$ in $0 \leq t \leq T_s$. The pulse shapes $g(t)$ studied here are defined in Appendix D in the compendium (see also pages 86–87). Furthermore, in this exercise all pulses have duration $T = T_s$.

Execute the file **spektral.m**

Seven figures are shown on the screen.

Part B1: Mainlobe and sidelobes

We know from (2.227) on page 93 in the compendium that the power spectral density for bandpass M-ary PAM in this case is,

$$R(f) = \frac{\bar{P}}{2E_g} \left(\underbrace{|G(f + f_c)|^2}_{\text{around } -f_c} + \underbrace{|G(f - f_c)|^2}_{\text{around } +f_c} \right)$$

Figures 1-5 show the power spectral density $R(f)$ in dB, for frequencies f around $+f_c$. The figures show $10 \log_{10} (R(f))$, (normalized with the maximum value) for five different pulse shapes $g(t)$.

Note that the frequency content is located around **the carrier frequency $f_c = 10/T_s$, and the bit rate equals 19200 bps**.

Assume that $M = 16$, and determine for each of the power spectral densities in Figures 1-5: (***Write your answers in the table below.***)

   a) The double-sided width W of the mainlobe in kHz.
      (The **zoom** function is very useful.)

   b) The attenuation of the first sidelobe, relative to the mainlobe, in dB. The attenuation in dB is here denoted u.

   c) The pulse shape $g(t)$.

R(f)	W [kHz]	u [dB]	g(t)
Figure 1			
Figure 2			
Figure 3			
Figure 4			
Figure 5			

Part B2: Classification of pulse shapes

Figure 6 shows the five power spectral densities considered in Part B1. Determine which pulse shape is best (=1), next best (=2), ..., worst (=5) with respect to:

i) asymptotic decay of the sidelobes   ii) width of the mainlobe.

Write the corresponding pulse shapes in the table below.

	Classification of pulse shapes	
	Asymptotic decay	Width of mainlobe
1 (best)		
2		
3		
4		
5 (worst)		

Which pulse shape do you recommend, and why?

....

Part B3: Bit rate & Bandwidth

Figure 7 shows normalized power spectral densities in dB for five different values of M. *The same pulse shape is used in all five cases in Figure 7* (it is one of the pulse shapes studied in Parts B1 and B2).
Observe that the power spectral densities in Figure 7 are shown as functions of fT_b, and they are located around **the carrier frequency $f_c = 10/T_b = 192000$ Hz**.

Select two of the five cases in Figure 7. For the two selected cases determine the values of M that are used (the zoom-function is useful).

Answer: ....

Determine the bandwidth efficiencies for the two selected cases in Figure 7.

Answer: ....

Which M corresponds to the case with the smallest width of the mainlobe, and how much of the total signal power is confined within the frequency interval 187900 Hz $\leq |f| \leq$ 196100 Hz in this case?

Answer: . . . .

Note! The laboratory assistent must check your answers before ending this laboratory lesson.