Sampling and aliasing
Amplitude modulation

Signals and codes (SK)

Department of Transport Telematics
Faculty of Transportation Sciences, CTU in Prague

Exercise 3

Exercise content

- Aliasing
  - Computing aliases and folded aliases of sinusoids
- Amplitude modulation
  - Plotting signals
  - Plotting the spectrum

Exercises

Exercise 03_1: Sampling, aliasing and folding of sinusoids – creating a script

Consider continuous time sinusoid with fundamental frequency f_0 = 100 Hz, phase shift $\Phi = \pi/3$ and amplitude $A = 1$.

Create a script, that will plot original signal, its aliases and folded aliases. Perform the following steps:

a) Define the parameters:

```
%% defining parameters

amp=1; %amplitude of original signal
f0=100; % frequency [Hz] of original signal
phi0=pi/3; %phase shift [rad] of original signal
fs=400; %sample frequency for sampling the original signal
oversampling=100; %for plotting aliases
noT=2; %number of periods of original signal to be plotted
i_alias = 1; %which ith alias will be plotted
i_fold = 1; %which ith folded alias will be plotted
```

Help:
1) you can declare
`t_sparse` using `fs`
`t_dense` using `fs*oversampling`
`x_sparse` using `t_sparse`
`x_dense` using `t_dense`
2) then define

```
om_hat = ;
om_alias_i = ;
om_fold_i = ;
f_alias_i = ;
f_fold_i = ; % negative frequency
y_alias_n = ;
y_fold_n = ; % negative phase
```

3) then create the plots according to subtask b)

b) Plot the following graphs in one figure:

1. Original sinusoid in black (use `t_dense` time, use `LineSpec '-k'`)
2. Original sinusoid stem plot in red (use `t_sparse time`, use `LineSpec '-r'`)
3. `i_alias`th signal in blue dashed line (use `LineSpec '--b'`) with stating respective frequency in legend
4. `i_fold`th signal in cyan dashed line (use `LineSpec '--c'`) with stating respective frequency in legend

c) State frequencies `f0` and `fs` within the title of figure from subtask b), use command `title`

Help: command for the legend:

```
legend('original waveform','samples at fs',sprintf('%d. alias of f = %.1f Hz',i_alias,f_alias_i),sprintf('%d. folded alias of f = %.1f Hz',i_fold,f_fold_i),'location','eastoutside');
```

Exercises

Exercise 03_2: Sampling, aliasing and folding of sinusoids – using created script

Consider continuous time sinusoid with fundamental frequency f_0 = 100 Hz, phase shift $\Phi = \pi/3$ and amplitude A = 1, the same as in exercise 03_1.

Use the script created in exercise 03_1 to show

a) correct sampling with fs = 800 Hz within 1 period, show 2nd alias and 2nd folded alias.

   1. Find a formula for frequency `f_i_alias` in terms of `f0`, `i_alias` and `fs`
   2. Find a formula for frequency `f_i_fold` in terms of `f0`, `i_fold` and `fs`

b) sampling with Nyquist rate *fs* = 200 Hz within 3 periods, show 1st alias and 1st folded alias

c) undersampling with fs = 180 Hz within 5 periods, show 1st alias and 1st folded alias. Which signal would be reconstructed? What is the relationship between reconstructed signal and original signal? (*correct answer: original signal is 1st folded alias of the reconstructed signal*).

d) undersampling with fs = 80 Hz within 5 periods, show -1st alias and -1st folded alias. Which signal would be reconstructed? What is the relationship between reconstructed signal and original signal?

Help: nothing difficult, you are just modifying parameters

Exercises

Exercise 03_3: Amplitude modulation types and their spectrum

Consider amplitude modulated signals. Create a script, that will plot the modulating signal, carrier signal , modulated signal and spectrum of modulated signal according to the instructions below.

a) Define the parameters:

```
%% defining parameters

sig_modulating_a=1; % amplitude
sig_modulating_f=10; % frequency, enter integer
sig_modulating_p=pi/4; % initial phase

sig_carrier_a=1;
sig_carrier_f=100; % frequency, enter integer multiple of sig_modulating_f
sig_carrier_p=0;

m=0.8; %modulation depth

fs=10000; % sample frequency of plotting
noT=5; %periods of modulating signal to be plotted

modulation_type='AMDSB'; % enter 'AMDSB' or 'AMDSBSC'
```

b) Determine modulating signal, carrier signal and modulated signal and plot them above one another in one figure.

c) Use and modify scripts from the Exercise 02_1 to plot the spectrum of modulated signal. The figure shall contain 4 plots side by side: (1.) modulated signal, (2.) magnitudes of Fourier coefficients {ak}, (3.) phases of {ak} and (4.) synthesised signal (just for verifying purpose)

Help: you can use the following code to switch between modulation types

```
switch modulation_type
    case 'AMDSB'
        sig_modulated = (1+m*sig_modulating).*sig_carrier;
    case 'AMDSBSC'
        sig_modulated = (m*sig_modulating).*sig_carrier;
end
```