Experiments

Two experiments to illustrate the effects that sampling introduces:

1. Sampling a chirp signal.
2. Sampling a rotating phasor.
Experiment: Sampling a Chirp Signal

- **Objective:** Directly observe folding and aliasing by means of a chirp signal.

- **Experiment Set-up:**
  - Set sampling rate. Baseline: $f_s = 44.1$KHz (oversampled), Comparison: $f_s = 8.192$KHz (undersampled)
  - Generate a (sampled) chirp signal with instantaneous frequency increasing from 0 to 20KHz in 10 seconds.
  - Evaluate resulting signal by
    - playing it through the speaker,
    - plotting the periodogram.

- **Expected Outcome?**

- **Expected Outcome:**
  - Directly observe folding and aliasing in second part of experiment.
Periodogram of undersampled Chirp
%% Parameters
fs = 8192;  % 44.1KHz for oversampling, 8192 for undersampling

% chitp: 0 to 20KHz in 10 seconds
fstart = 0;
fend = 20e3;
dur = 10;

%% generate signal
tt = 0:1/fs:dur;
psi = 2*pi*(fend-fstart)/(2*dur)*tt.^2;  % phase function
xx = cos(psi);

%% spectrogram
spectrogram( xx, 256, 128, 256, fs,'yaxis');

%% play sound
soundsc( xx, fs);
Introduction to Sampling

Apparent and Normalized Frequency

\[ f \]
\[ d \]
\[ a \]
\[ 0 \]
\[ 0.5 \]
\[ 1 \]
\[ Over-sampling \]
\[ Folding \]
\[ Aliasing \]
\[ Folding \]

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ECE 201: Intro to Signal Analysis
Experiment: Sampling a Rotating Phasor

- **Objective:** Investigate sampling effects when we can distinguish between positive and negative frequencies.

- **Experiment Set-up:**
  - Animation: rotating phasor in the complex plane.
  - Sampling rate describes the number of “snap-shots” per second (strobes).
  - Frequency the number of times the phasor rotates per second.
    - positive frequency: counter-clockwise rotation.
    - negative frequency: clockwise rotation.

- **Expected Outcome?**

- **Expected Outcome:**
  - Folding: leads to reversal of direction.
  - Aliasing: same direction but apparent frequency is lower than true frequency.
True and Apparent Frequency

\[ f_s = 20 \]

<table>
<thead>
<tr>
<th>True Frequency</th>
<th>-0.5</th>
<th>0</th>
<th>0.5</th>
<th>19.5</th>
<th>20</th>
<th>20.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparent Frequency</td>
<td>-0.5</td>
<td>0</td>
<td>0.5</td>
<td>-0.5</td>
<td>0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

► Note, that instead of folding we observe negative frequencies.
  ► occurs when true frequency equals 9.5 in above example.
%% parameters
fs = 10; % sampling rate in frames per second
dur = 10; % signal duration in seconds

ff = 9.5; % frequency of rotating phasor
phi = 0; % initial phase of phasor
A = 1; % amplitude

%% Prepare for plot
TitleString = sprintf('Rotating Phasor: _f_d_ = %5.2f', ff/fs);
figure(1)

% unit circle (plotted for reference)
cc = exp(1j*2*pi*(0:0.01:1));
ccx = A*real(cc);
cci = A*imag(cc);
%% Animation
for tt = 0:1/fs:dur
    tic; % establish time-reference
    plot(ccx, cci, ':', ...
         [0 A*cos(2*pi*ff*tt+phi)], [0 A*sin(2*pi*ff*tt+phi)], '-ob');
    axis('square')
    axis([-A A -A A]);
    title(TitleString)
    xlabel('Real')
    ylabel('Imag')
    grid on;

    drawnow % force plots to be redrawn
    te = toc;

    % pause until the next sampling instant, if possible
    if ( te < 1/fs)
        pause(1/fs-te)
    end
end