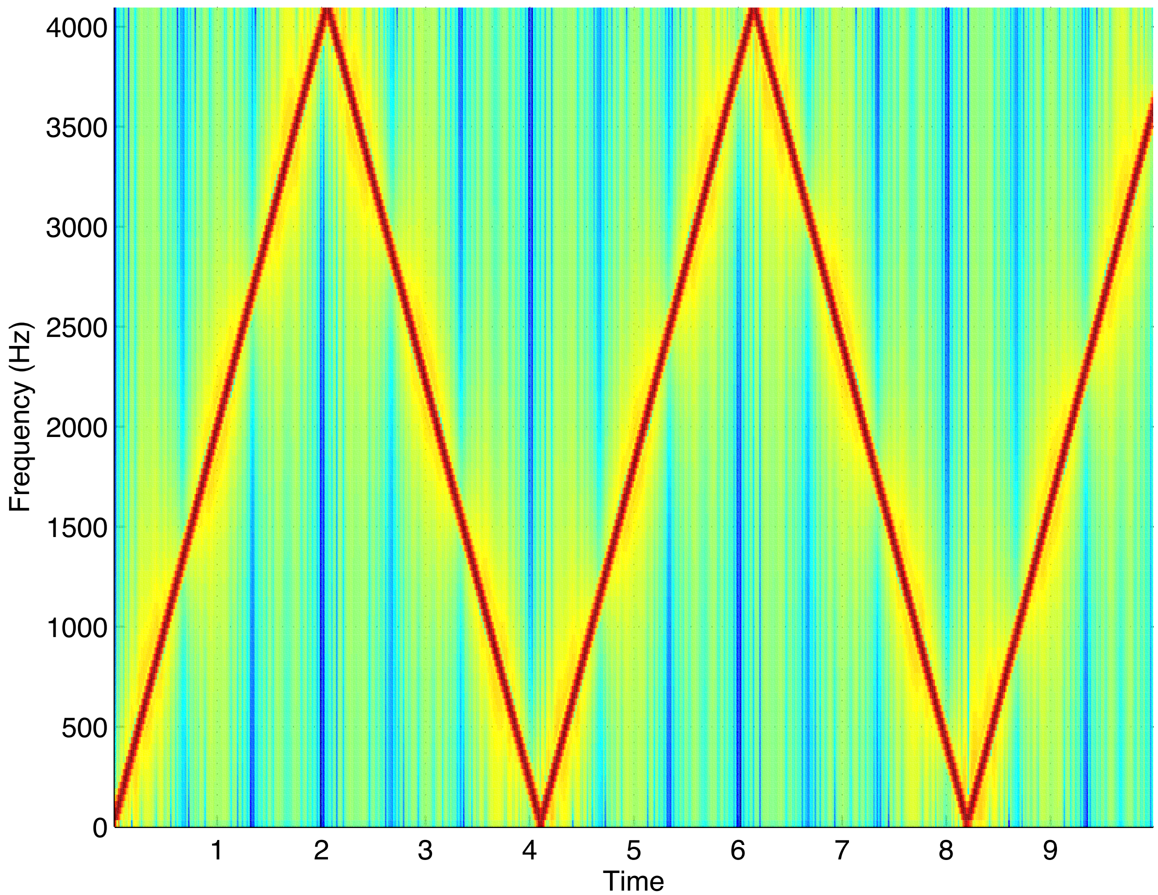
Experiments

- Two experiments to illustrate the effects that sampling introduces:
  1. Sampling a chirp signal.
  2. Sampling a rotating phasor.

Experiment: Sampling a Chirp Signal

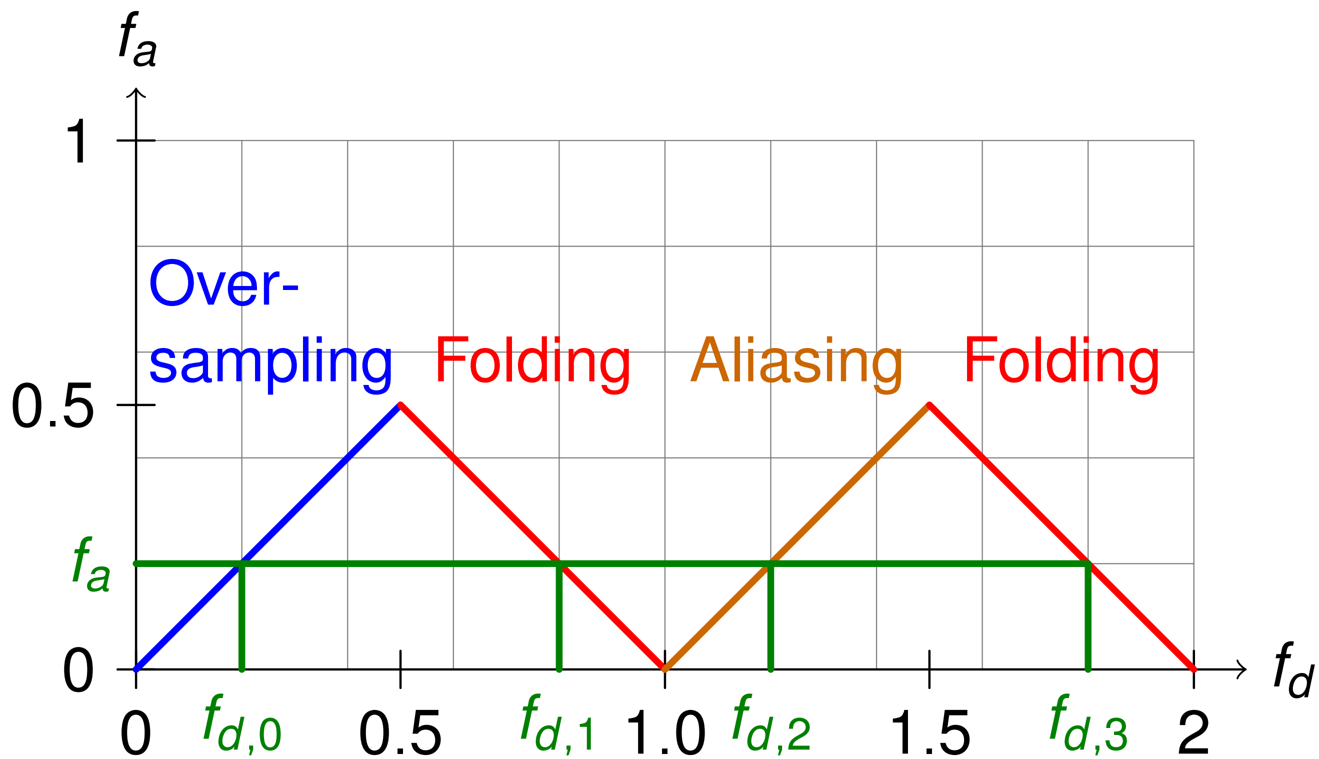
- **Objective:** Directly observe folding and aliasing by means of a chirp signal.
- **Experiment Set-up:**
  - Set sampling rate. Baseline: $f_s = 44.1$KHz (oversampled), Comparison: $f_s = 8.192$KHz (undersampled)
  - Generate a (sampled) chirp signal with instantaneous frequency increasing from 0 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);
```

Apparent and Normalized Frequency



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

$f_s = 20$

True Frequency	-0.5	0	0.5	19.5	20	20.5
Apparent Frequency	-0.5	0	0.5	-0.5	0	0.5

- 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
```