Modulation

Modulation:

The process where parameters of a sinusoidal signal (amplitude, frequency and phase) are modified or varied by an audio signal.

We have met some example effects that could be considered as a class of modulation already:

Amplitude Modulation: Wah-wah, Phaser

Frequency Modulation: Audio synthesis technique

Phase Modulation: Vibrato, Chorus, Flanger

We will now look at some other Modulation effects.

Ring Modulation

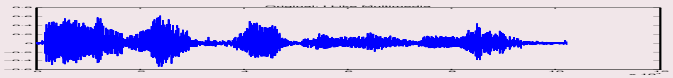
Ring modulation (RM)

RM is where the audio *modulator* signal, $x(n)$ is **multiplied** by a sine wave, $m(n)$, with a *carrier* frequency, f_c.

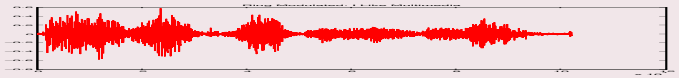
- This is very simple to implement digitally:

$$y(n) = x(n).m(n)$$

- Although audible result is easy to comprehend for simple signals things get more complicated for signals having numerous partials
- If the **modulator** is also a sine wave with frequency, f_x then one hears the sum and difference frequencies: $f_c + f_x$ and $f_c - f_x$, for example.
- When the input is *periodic* with at a **fundamental** frequency, f_0, then a spectrum with amplitude lines at frequencies $|kf_0 \pm f_c|$.
- Used to create robotic speech effects on old sci-fi movies and can create some odd almost non-musical effects if not used with care. (Original speech). *ring_modllikeMM.m code here*



Original Signal



Ring Modulated Signal (Robotic)

MATLAB Ring Modulation

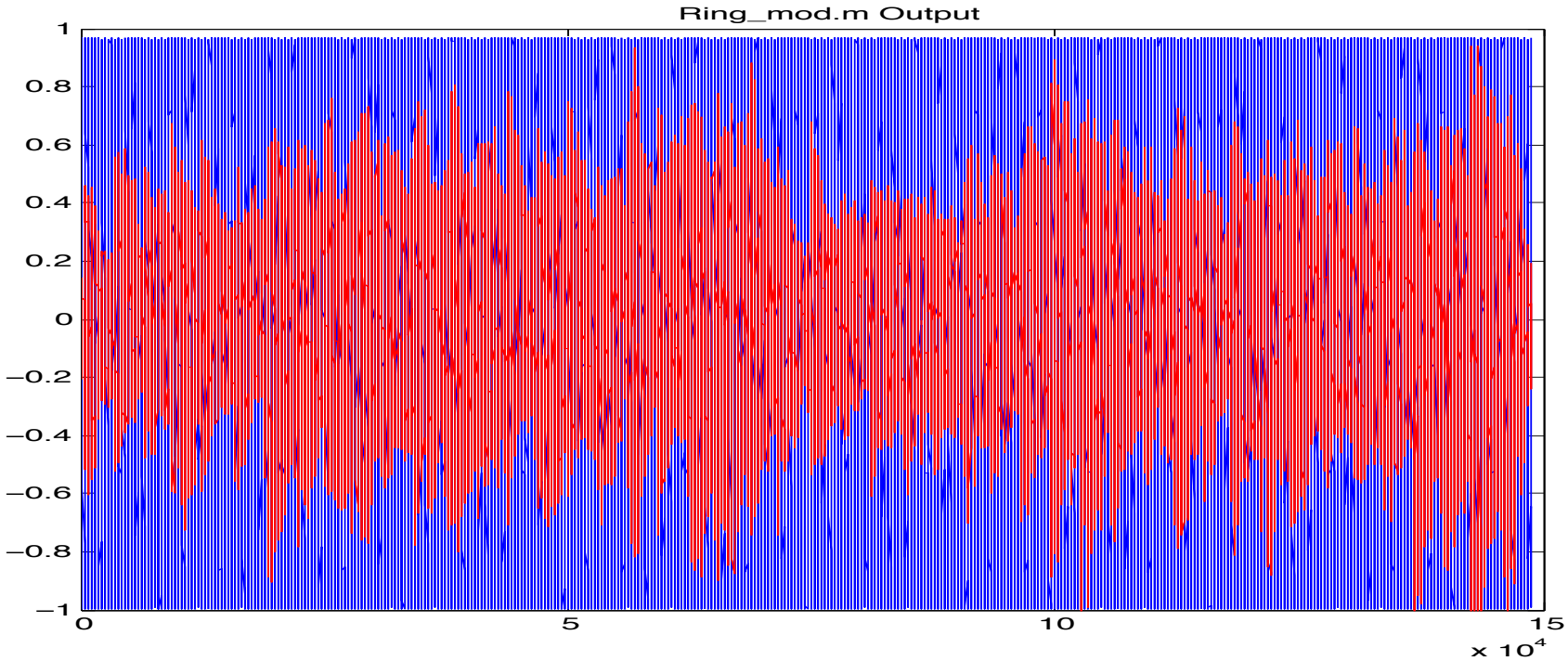
Two examples

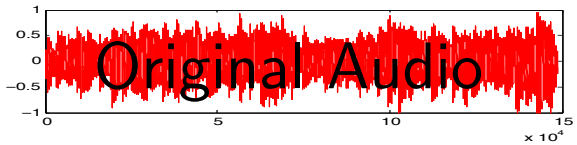
An audio sample and a sine wave being modulated by a sine wave.

Example 1: Audio RM, ring_mod.m

```
% read the sample waveform
[x,Fs] = audioread('acoustic.wav');

index = 1:length(x);

% Ring Modulate with a sine wave frequency Fc
Fc = 440;
carrier= sin(2*pi*index*(Fc/Fs))';

% Do Ring Modulation
y = x.*carrier;

% write output
audiowrite('out_ringmod.wav', y,Fs);
```

Example 1: Audio RM Output





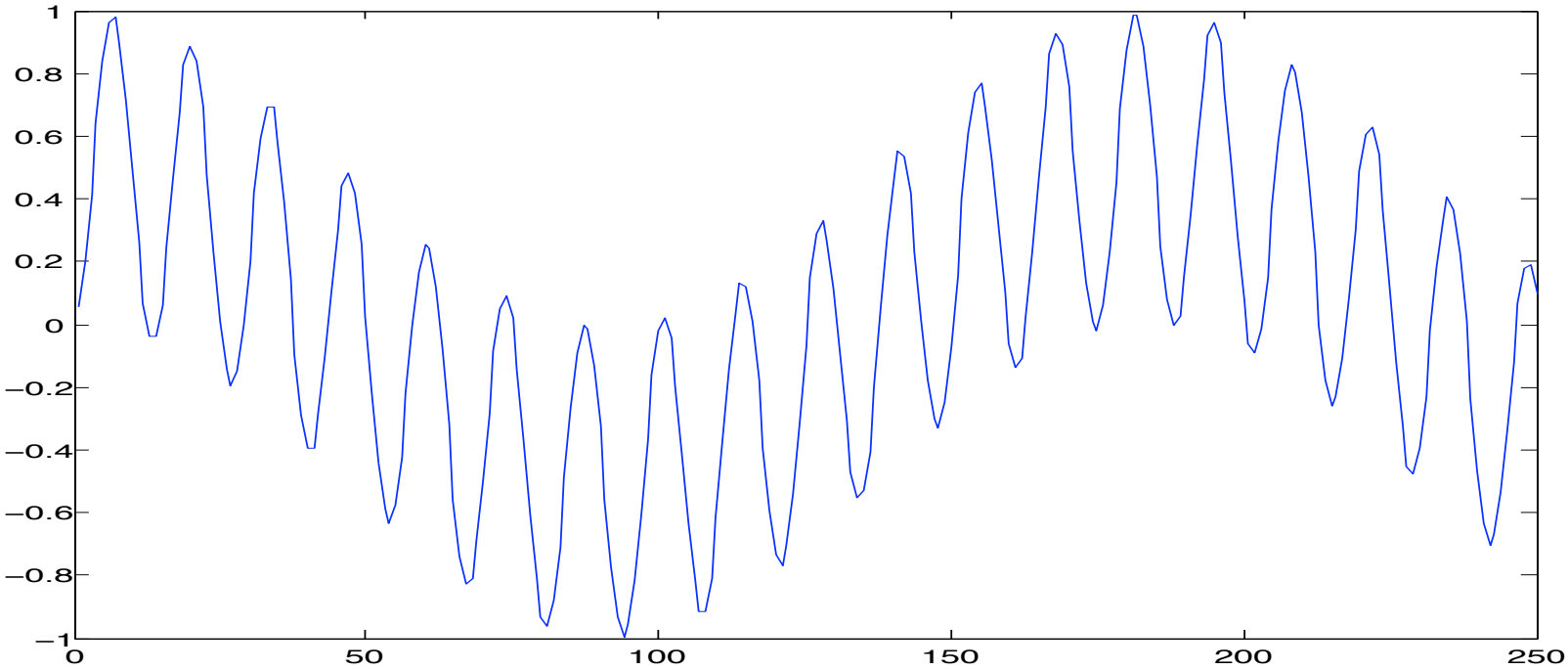
Click image or here to hear: original audio, ring modulated audio.

MATLAB Ring Modulation: Two sine waves

Example 2: Two sine waves RM ring_mod_2sine.m

```
% Ring Modulate with a sine wave frequency Fc
Fc = 440;
carrier= sin(2*pi*index*(Fc/Fs))';

%create a modulator sine wave frequency Fx
Fx = 200;
modulator = sin(2*pi*index*(Fx/Fs))';

% Ring Modulate with sine wave, freq. Fc
y = modulator.*carrier;

% write output
audiowrite('twosine_ringmod.wav', y,Fs);
```

Example 2: Two Sine RM Output



Output of Two sine wave ring modulation ($f_c = 440$, $f_x = 380$)

Click image or here to hear:

Two RM sine waves ($f_c = 440$, $f_x = 200$)

Amplitude Modulation

Amplitude Modulation (AM)

AM is defined by:

$$y(n) = (1 + \alpha m(n)).x(n)$$

- Normalise the peak amplitude of $m(n)$ to 1.
- α is *depth of modulation*

  $\alpha = 1$ gives maximum modulation
  $\alpha = 0$ tuns off modulation
- $x(n)$ is the audio **carrier** signal
- $m(n)$ **is** a low-frequency oscillator **modulator**.
- When $x(n)$ and $m(n)$ **both** sine waves with frequencies f_c and f_x respectively we here **three** frequencies: carrier, difference and sum: $f_c, f_c - f_x, f_c + f_x$.

Amplitude Modulation: Tremolo

AM Example: tremolo

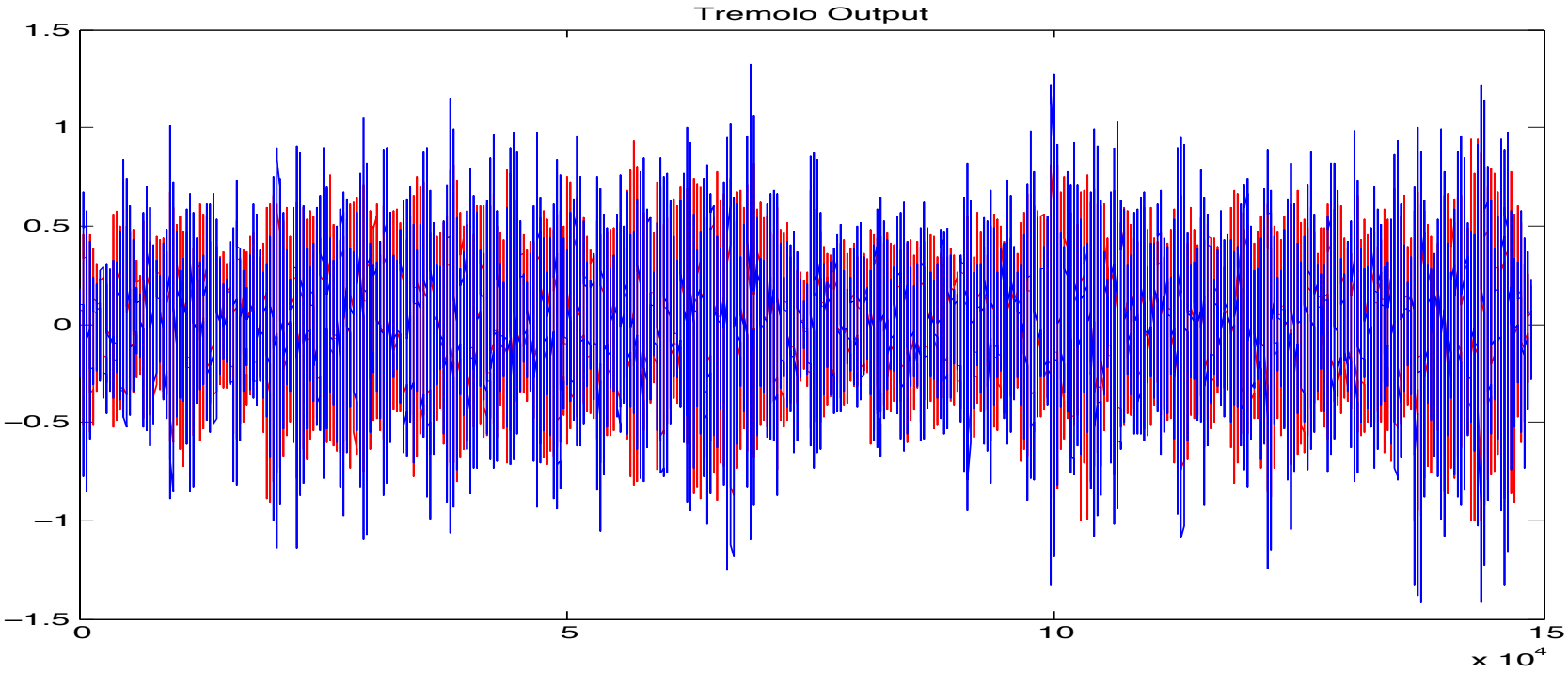
Modulate the amplitude:

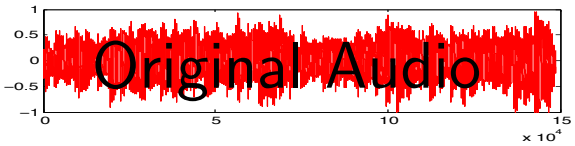
- Set modulation frequency of a sine wave to below 20Hz.

tremolo1.m

```
filename='acoustic.wav';% read the sample waveform
[x,Fs] = audioread(filename);

index = 1:length(x);

Fc = 5;
alpha = 0.5;

trem=(1+ alpha*sin(2*pi*index*(Fc/Fs)))';
y = trem.*x;

% write output
audiowrite('out_tremolo1.wav', y,Fs);
```

Amplitude Modulation: Tremolo Output





Click image or here to hear: original audio, AM tremolo audio.

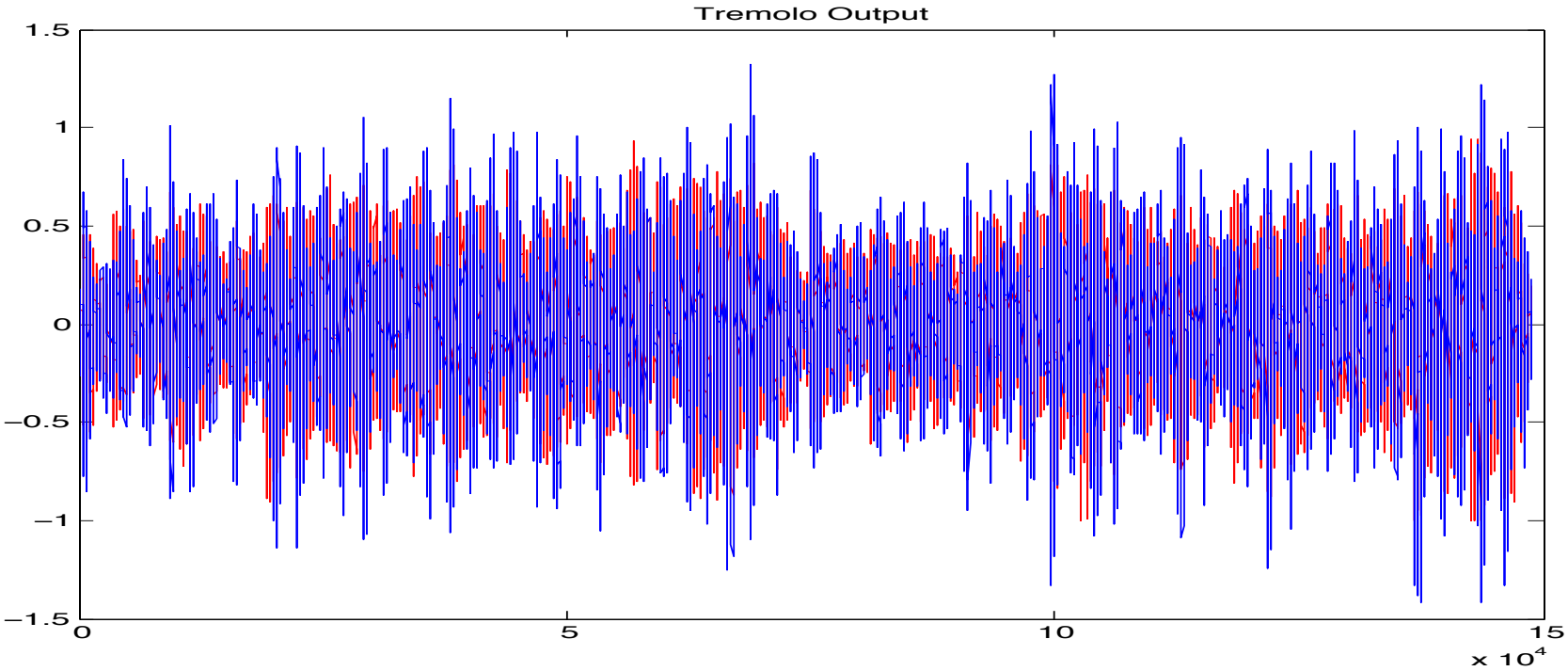
Tremolo via Ring Modulation

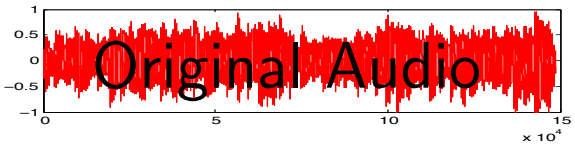
tremolo2.m

If you ring modulate with a **triangular wave** (or try another waveform) you can get **tremolo via RM**.

```
% read the sample waveform
filename='acoustic.wav';
[x,Fs] = audioread(filename);

% create triangular wave LFO
delta=5e-4;
minf=-0.5;
maxf=0.5;

trem=minf:delta:maxf;
while(length(trem) < length(x) )
   trem=[trem (maxf:-delta:minf)];
   trem=[trem (minf:delta:maxf)];
end

%trim trem
trem = trem(1:length(x))';
```

Tremolo via Ring Modulation Output





Click here to hear: original audio, RM tremolo audio.