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Implementation of Envelope Detector and Coherent Detection

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ABSTRACT

As a part of this semester we are working on the implementation of the Enveloper detector and Coherent detection using Matlab. As we know that both of the above mentioned topics are very useful for fetching useful information from a signal.

An envelope detector is an electronic circuit that takes a (relatively) high-frequency amplitude modulated signal as input and provides an output which is the demodulated envelope of the original signal. An envelope detector is sometimes called a peak detector.

Coherent detection originates from radio communications, where a local carrier mixes with the received radio frequency (RF) signal to generate a product term. As a result, the received RF signal can be frequency translated and demodulated. One such good example is Modulation filtering, which has been previously described as several related approaches to achieve modification of speech temporal dynamics, is shown to be less effective than intended.

DATASET

RFS1k is an audio content analysis dataset consisting of 1000 heterogeneous sound files encoded in 44.1kHz/16bit PCM WAV format. It was gathered at random from Freesound by querying their API for random integer sound IDs. The dataset allows only one sound per unique Freesound user to discourage overrepresentation of source material, recording chain, etc.

The dataset consists of 1000 sounds originally encoded and uploaded to Freesound as 44.1kHz/16bit PCM WAV files. For each WAV file, the dataset includes a JSON file of metadata and two preview OggVorbis encodings of low and high quality. It is useful for unsupervised learning tasks, some supervised tasks (the metadata contains user-provided tags and descriptions) and black-box analysis of sound manipulation techniques.

THEORY

As said in abstract we are going to implement -

1) Enveloper Detector -

   The signal's envelope is equivalent to its outline, and an envelope detector connects all the peaks in this signal. Envelope detection has numerous applications in the fields of signal processing and communications, one of which is amplitude modulation (AM) detection. Amplitude modulation (AM) is a modulation technique used in electronic communication, most commonly for transmitting information via a radio carrier wave. In amplitude modulation, the amplitude (signal strength) of the carrier wave is varied in proportion to the waveform being transmitted. That waveform may, for instance, correspond to the sounds to be reproduced by a loudspeaker, or the light intensity of television pixels. An envelope detector is an electronic circuit that takes a high-frequency signal as input and provides an output which is the envelope of the original signal.

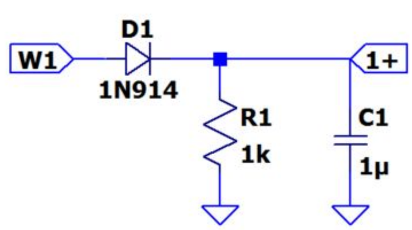
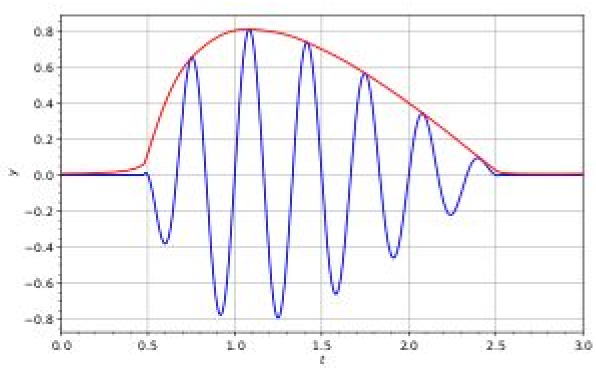


Fig-1: Basic Envelope detector Circuit

For implementing it in MATLAB we used a squaring and low pass filtering method. It involves squaring the input signal and sending this signal through a low pass filter. Squaring the signal effectively demodulates the input by using itself as its own carrier wave. This means that half the energy of the signal is pushed up to higher frequencies and half is shifted down toward DC. You then downsample this signal to reduce the sampling frequency. You can do downsampling if the signal does not have any high frequencies which could cause aliasing. Otherwise an FIR decimation should be used which applies a lowpass filter before downsampling the signal. After this, pass the signal through a minimum-phase, low pass filter to eliminate the high frequency energy. Finally you are left with only the signal envelope.

To maintain the correct scale, you must perform two additional operations. First, you must amplify the signal by a factor of two. Since you are keeping only the lower half of the



signal energy, this gain matches the final energy to its original energy. Second, you must take the square root of the signal to reverse the scaling distortion that resulted from squaring the signal. This envelope detection method is easy to implement and can be done with a low-order filter, which minimizes the lag of the output. An AM signal encodes the information into the carrier wave by varying its amplitude in direct sympathy with the analogue signal to be sent. There are two methods used to demodulate AM signals: The envelope detector is a very simple method of demodulation that does not require a coherent demodulator.

2) Coherent Detector -

The process of extracting an original message from the signal wave is known as detection or demodulation. In coherent detection the local carrier generated at the receiver is phase locked with the carrier at the transmitter. Hence it is also called synchronous detection. Coherent lightwave communications utilize optical amplitude, phase, and frequency as information-bearing signals.

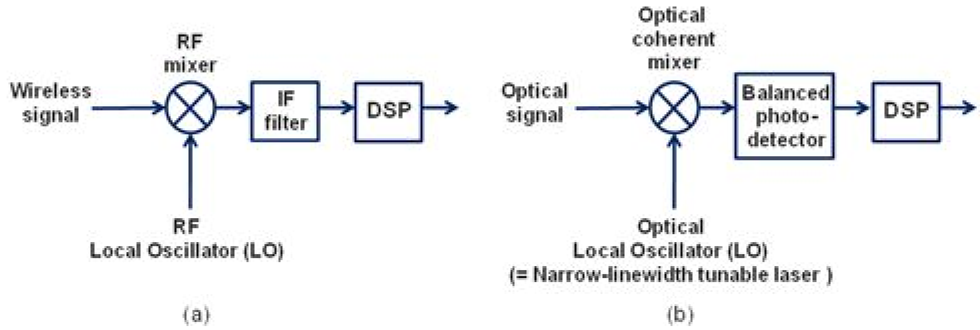


Fig.1 A simple illustration of how coherent detection works for (a) wireless systems, and (b) optical coherent systems.

The idea of coherent detection in optical communication was first proposed in the 1980s. At that time, the major advantages of coherent detection are much higher receiver sensitivity (shot-noise limited receiver) with up to 10–20 dB link budget improvement compared to IM-DD systems. Other advantages include enhanced frequency selectively to separate WDM channels in the electrical domain, and alternative modulation formats, for example, phase-shift keying (PSK). Therefore, it promised to extend the repeaterless transmission beyond 50–100 km, which was of great benefit to any long haul transmission system in terms of overall system cost.

It provides several key advantages compared to direct detection, for example it has a greatly improved receiver sensitivity, it can extract amplitude, frequency, and other phase related information from an optical carrier, and consequently can achieve much higher capacity in the same bandwidth.

MATLAB Implementation:

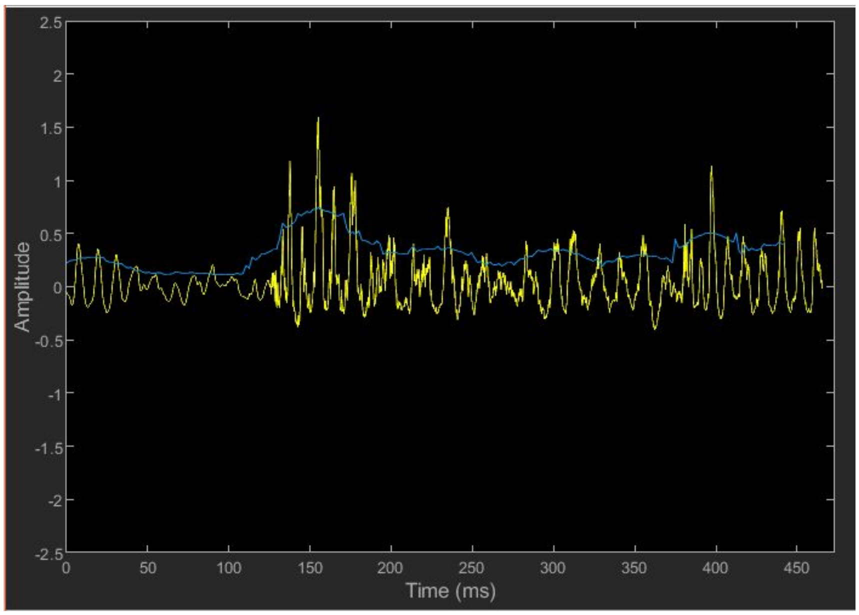
CODE:

```
aud = dsp.AudioFileReader('audio.wav');

%envelope detector

Fs = aud.SampleRate;
samples = 11000;
downfactor = 15;
frames = 10*downfactor;

lowpass1 = dsp.FIRFilter('Numerator', firpm(20, [0 0.03 0.1 1], [1 1 0 0]));

N=60;

timescope1 = dsp.TimeScope('NumInputPorts', 2,'Name', 'Envelope
detection','SampleRate', [Fs Fs/downfactor],'TimeDisplayOffset', [(N/2+frames)/Fs
0], 'TimeSpanSource', 'Property', 'TimeSpan', 0.45, 'YLimits', [-2.5 2.5]);


for i=1:samples/frames
    tmp = step(aud);
    tmp = (1+tmp(:,1)).*tmp(:, 2);
    tmp1 = 2*tmp.*tmp;
    tmp2 = sqrt(step(lowpass1, downsample(tmp1, downfactor)));
    step(timescope1, tmp, tmp2);
end

%Coherent Detection

au=aud();
t=linspace(0,10,length(au));
Ft=real(au);
Fc=1000000;
nf=1+0.5*Ft;
coss=permute(cos(2*pi*Fc*t),[2,1]);
z=nf.*coss;

coherent=z.*coss;
disp(size(coherent));
plot(t,coherent);
title('coherent detection');
```

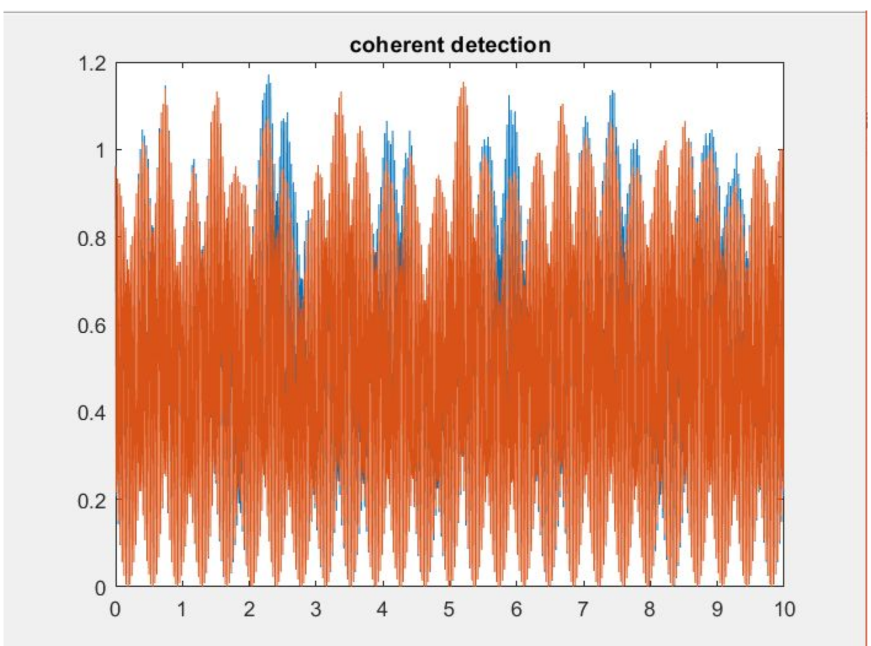
Result

As we know about the benefit of modulation as well as demodulation by the help of carrier waves. As for performing demodulation as well as extracting the valuable information from the signal is also an important part of signals. On applying envelope detection to a (relatively) high-frequency amplitude modulated signal as input, it provided an output which is the demodulated envelope of the original signal. Coherent detection helps us to extract various signal parameters. On applying both the techniques we got this -

Envelope detector:



Coherent detection:



CONCLUSION

After working on this project we got good insights on signals, modulation, demodulation, coherent detection, and envelope detection. Also working on MATLAB was a good experience to apply learned techniques for the implementation. We would like to extend this project by implementation both modulation in ADHALM 1000 and in the circuit as well. Also during working on the project we found the implementation of modulation and detection in audio processing i.e. modulation filtering of speech.

REFERENCE

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