In [1]:
```
import os
import glob

import numpy as np

import matplotlib.pyplot as plt
import IPython.display as ipd
import IPython
import matplotlib.colors as colors

from scipy import signal
from copy import deepcopy

import utils
```

In [2]:
```
dataurl = 'http://www.openslr.org/resources/1/waves_yesno.tar.gz'
```

In [3]:
```
utils.download_and_extract_data(dataurl)
```

In [4]:
```
path_to_sound_data = './waves_yesno/'
```

In [5]:
```
### STFT hyperparameters

nperseg = 512
window_size = 5
```

In [6]:
```
noise_std_array = [1e-1];  ## all noise levels to consider. feel free to pl
```

In [7]:
```
### for plotting

ini = 34500-1
end = 37500+1

ini2 = 34875
end2 = 35025
```

Creating Dataset

In [8]:
```
train_dataset, train_fs_array, train_max_array, val_dataset, val_fs_array,
```

train_dataset and val_dataset contains time domain signals normalized so that maximum amplitude is 1

In [9]:
```
max( x.max() for x in train_dataset )
```

Out[9]:
```
1.0
```

The actual maximum amplitude of signal is saved in train_max_array and val_max_array. We will use this maximum value to un-normalize the signals before plotting or listening to it.

actual_signal[k] = train_dataset[k] * train_max_array[k]

The sampling rate of each sigal is given in train_fs_array and val_fs_array. In our case, all of them have same sampling rate. We will use sampling rate for stft function

Get Noise Function

In [10]:
```
def get_noise(data, noise_std = 0.1):
    noise = np.random.randn(*data.shape);
    noise = noise * noise_std;
    return noise
```

STFT Hard and Block Thresholding

In [11]:
```
def plot_stft(stft_array, save_str=''):

    """ utility function to plot stft """
    f, t, Zxx = stft_array;
    Zxx_abs = np.abs(Zxx)
    Zxx_abs[Zxx_abs<1e-5] = 1e-5
    plt.figure()
    plt.pcolormesh(t, f,Zxx_abs, norm=colors.LogNorm(vmin=Zxx_abs.min(), vm
    tick_size = 18
    label_size = 18
    cb = plt.colorbar()
    plt.tick_params(labelsize=tick_size)
    cb.ax.tick_params(labelsize=tick_size)
    plt.ylabel('Frequency (Hz)',fontsize=label_size)
    plt.xlabel('Time (s)',fontsize=label_size)
    plt.savefig('plots/stft_denoising_'+save_str+'_stft.pdf',bbox_inches="t
    plt.show()
```

In [12]:
```
def get_block_L2_norm(mat, window_size):

    """ mat: an nxn matrix
        window_size: postivie integer (assume odd)
        return: nxn matrix where the (i,j)th entry is the L2 norm of a wind
                neighbourhood centered at (i, j)

        to obtain an nxn output, assume that edges are zero padded.

        hint: implement using a convolution

        sample output for get_block_L2_norm(np.ones([5, 5]), 3):

      [[2.        , 2.44948974, 2.44948974, 2.44948974, 2.        ],
       [2.44948974, 3.        , 3.        , 3.        , 2.44948974],
       [2.44948974, 3.        , 3.        , 3.        , 2.44948974],
       [2.44948974, 3.        , 3.        , 3.        , 2.44948974],
       [2.        , 2.44948974, 2.44948974, 2.44948974, 2.        ]]
    """
    pad = (window_size-1)//2
    mat = np.sqrt(signal.convolve2d(mat*mat,np.ones((window_size,window_siz


    return mat
```

Implement Hard and Block Thresholding

In [13]:
```
def stft_denoising(source, noise_std, fs, nperseg, thresh,
                   window_size, block_thresh = None, plot_res = True, ind=0

    """
    implements hard and block thresholding.

    thresh - threshold for hard thresholding. Thresholding is implemented p
    block_thresh - threshold for block thresholding. Thresholding is implem

    """

    noisy = source + get_noise(source, noise_std);

    if block_thresh is None:
        block_thresh = thresh;

    source_stft = signal.stft(source, fs = fs, nperseg=nperseg);
    noisy_stft = signal.stft(noisy, fs = fs, nperseg=nperseg);
    ## FILL YOUR CODE
    coeffs = noisy_stft[2]
    hardmask = np.greater(np.abs(coeffs),thresh)
    block12s= get_block_L2_norm(coeffs, window_size)
    blockmask= np.greater(block12s,block_thresh)

    denoised_stft = ( noisy_stft[0], noisy_stft[1], hardmask*coeffs)#HARD T
    block_denoised_stft =  ( noisy_stft[0], noisy_stft[1], blockmask*coeffs

    if plot_res:
        plot_stft(source_stft,save_str='_clean_'+str(ind));
        plot_stft(noisy_stft,save_str='_noisy_'+str(ind));
        plot_stft(denoised_stft,save_str='_denoised_'+str(ind));
        plot_stft(block_denoised_stft,save_str='_block_denoised_'+str(ind))

    _, source_istft =  signal.istft(source_stft[2], fs=fs, nperseg=nperseg)
    _, noisy_istft =   signal.istft(noisy_stft[2], fs=fs, nperseg=nperseg);
    _, denoised_istft =   signal.istft(denoised_stft[2], fs=fs, nperseg=npe
    _, block_denoised_istft =   signal.istft(block_denoised_stft[2], fs=fs,


    return np.real(source_istft), np.real(noisy_istft), np.real(denoised_is
```

Choosing Threshold Based on Train Error

We will compute the error for different values of threshold and pick the threshold based on the lowest error on the training set.

We don't really do any training here. The denoising method only has one hyperparameter - the threshold. We're picking it based on the training set.

The next cells should run off hand if you have filled get_block_L2_norm() and stft_denoising()

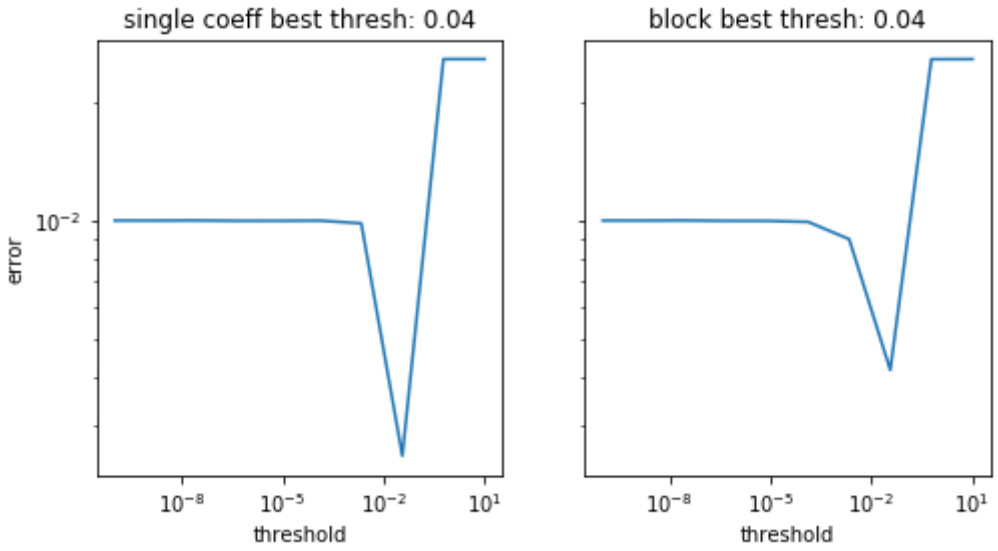
In [14]:
```
np.sqrt(1e-2)
```

Out[14]:
```
0.1
```

In [15]:
```
# threshold_array = [1e-10, 1e-8, 1e-6, 1e-4, 1e-2, 1e0, 1e2]

threshold_array = np.logspace(-10, 1, num = 10)
```

In [16]:
```
rror_dict = {}
lock_error_dict = {}
est_threshold_dict = {}
lock_best_threshold_dict = {}
or noise_std in noise_std_array:

   error_dict[noise_std] = np.zeros_like(threshold_array);
   block_error_dict[noise_std] = np.zeros_like(threshold_array);

   for thresh_i, thresh in enumerate(threshold_array):
       total_error = 0.0;
       block_total_error = 0.0;
       total_length = 0.0;
       for i, x in enumerate(train_dataset):
           rec_source, rec_noisy, rec_denoised, rec_denoised_block = stft_de
           total_error += np.linalg.norm( rec_denoised - rec_source)**2;
           block_total_error += np.linalg.norm( rec_denoised_block - rec_sou
           total_length += len(rec_source);

       error_dict[noise_std][thresh_i] = (total_error/total_length);
       block_error_dict[noise_std][thresh_i] = (block_total_error/total_leng

   print('noise std: ', noise_std);
   fig, axes = plt.subplots(1, 2, sharex=True, sharey=True, figsize = (8, 4)

   axes[0].loglog(threshold_array, error_dict[noise_std])
   axes[0].set_xlabel('threshold')
   axes[0].set_ylabel('error')

   best_threshold_dict[noise_std] = threshold_array[np.argmin(error_dict[noi

   axes[0].set_title('single coeff best thresh: '+str( round(best_threshold_

   axes[1].loglog(threshold_array, block_error_dict[noise_std])
   axes[1].set_xlabel('threshold')
     axes[1].set_ylabel('error')

   block_best_threshold_dict[noise_std] = threshold_array[np.argmin(block_er

   axes[1].set_title('block best thresh: '+str( round(block_best_threshold_d

   plt.show()

   print('='*50+'\n')
```

```
noise std:  0.1
```



==========

Comparison Between STFT Hard and Block Threshold

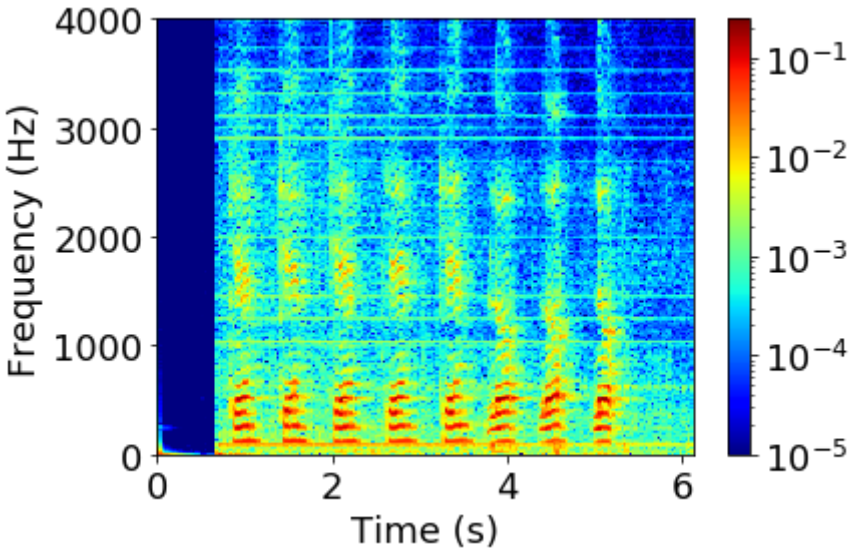
In [17]:
```
val_idx = 2

source = val_dataset[val_idx]
fs = val_fs_array[val_idx]
max_val = val_max_array[val_idx]
```

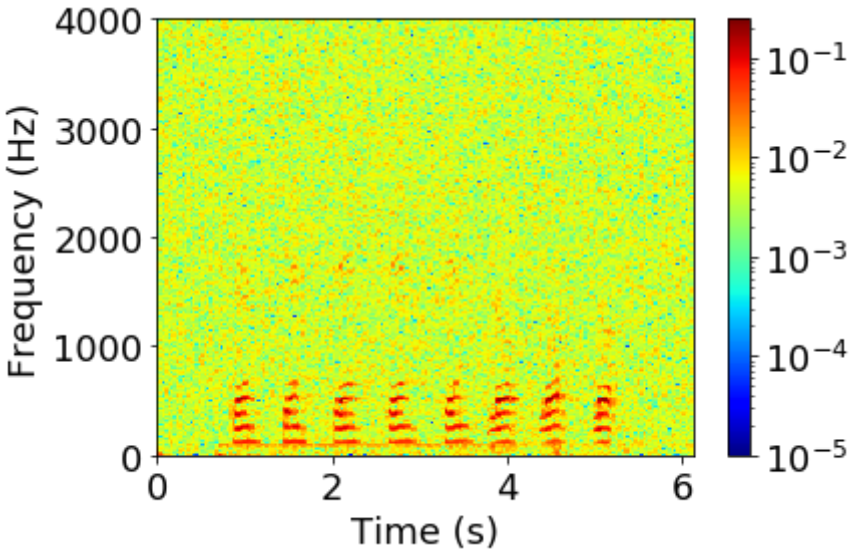
In [18]:
```
fig_size=(20,6)
```

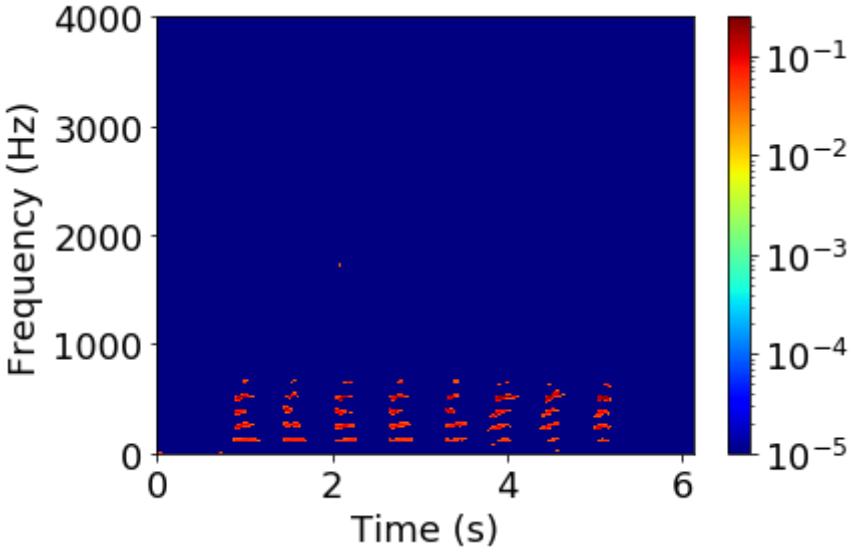
In [20]:
```
for ind_fig, noise_std in enumerate(noise_std_array):

    print('Noise Std: ', noise_std)

    noise_sample = get_noise(source, noise_std = noise_std);


    istft_source, istft_noisy, istft_denoised, istft_denoised_block = stft_d
                                                                      thresh = best
                                                                      window_size =
                                                                      block_thresh

    istft_denoised_block *= max_val
    istft_denoised *= max_val;
    istft_noisy *= max_val;
    istft_source *= max_val;

    print('STFT Denoised: ')
    IPython.display.display(ipd.Audio(istft_denoised, rate=fs))

    print('Block STFT Denoised: ')
    IPython.display.display(ipd.Audio(istft_denoised_block, rate=fs))

    label_size = 18
    font_size = 18

    t_indices = np.arange(len(istft_source))/fs

    plt.figure(figsize = fig_size)
    plt.plot(np.real(istft_source))
    plt.xlabel('Time (s)',fontsize=font_size)
    plt.tick_params(labelsize=label_size)

    plt.figure(figsize = fig_size)
    plt.plot(t_indices[ini:end],np.real(istft_denoised[ini:end]))
    plt.xlabel('Time (s)',fontsize=font_size)
    plt.tick_params(labelsize=label_size)
    plt.savefig('plots/stft_stft_denoised_' + str(ind_fig) + '.pdf',bbox_inc

    plt.figure(figsize = fig_size)
    plt.plot(t_indices[ini:end],np.real(istft_denoised_block[ini:end]))
    plt.xlabel('Time (s)',fontsize=font_size)
    plt.tick_params(labelsize=label_size)
    plt.savefig('plots/stft_block_denoised_' + str(ind_fig) + '.pdf',bbox_in



    plt.figure(figsize = fig_size)
    plt.plot(t_indices[ini2:end2],np.real(istft_source[ini2:end2]),'--o',mar
    plt.plot(t_indices[ini2:end2],np.real(istft_denoised[ini2:end2]),'x',col
    plt.plot(t_indices[ini2:end2],np.real(istft_noisy[ini2:end2]),'.',color=
    plt.xlabel('Time (s)',fontsize=font_size)
    plt.tick_params(labelsize=label_size)
    plt.legend(fontsize=font_size)
    plt.savefig('plots/stft_stft_denoised_' + str(ind_fig) + '_zoom.pdf',bbo

    plt.figure(figsize = fig_size)
```

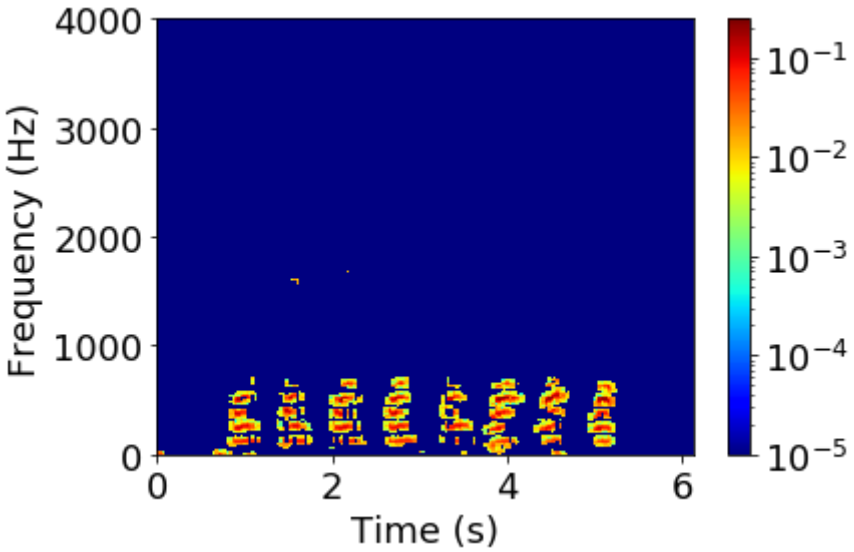
```
    plt.plot(t_indices[ini2:end2],np.real(istft_source[ini2:end2]),'--o',mar
    plt.plot(t_indices[ini2:end2],np.real(istft_denoised_block[ini2:end2]),'
    plt.plot(t_indices[ini2:end2],np.real(istft_noisy[ini2:end2]),'.',color=
    plt.xlabel('Time (s)',fontsize=font_size)
    plt.tick_params(labelsize=label_size)
    plt.legend(fontsize=font_size)
    plt.savefig('plots/stft_block_denoised_' + str(ind_fig) + '_zoom.pdf',bb

    plt.show()


    print('='*50 + '\n')
```

```
Noise Std:  0.1
```







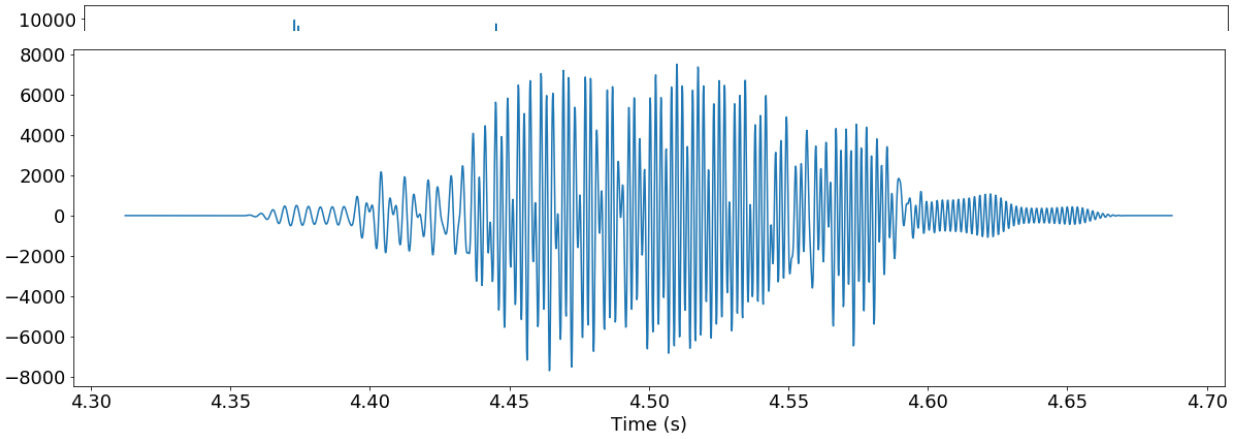


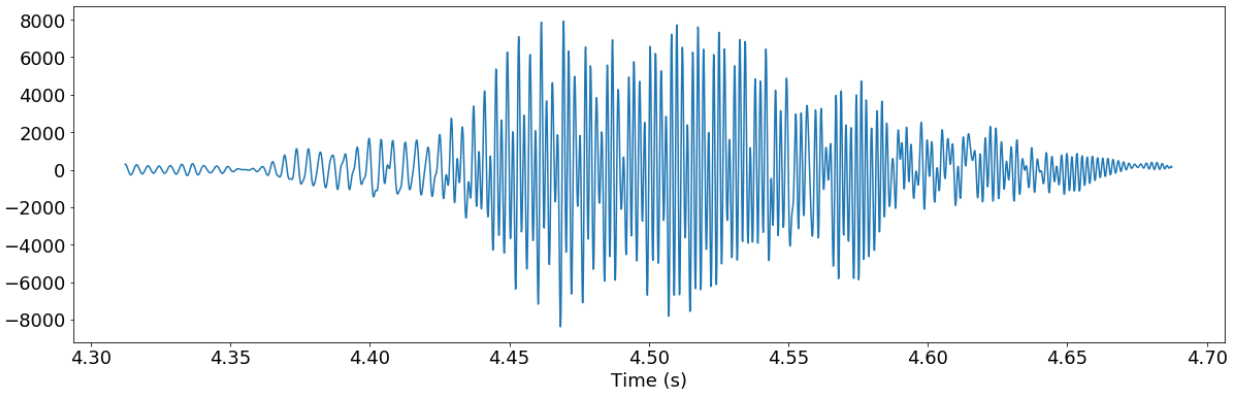
STFT Denoised:

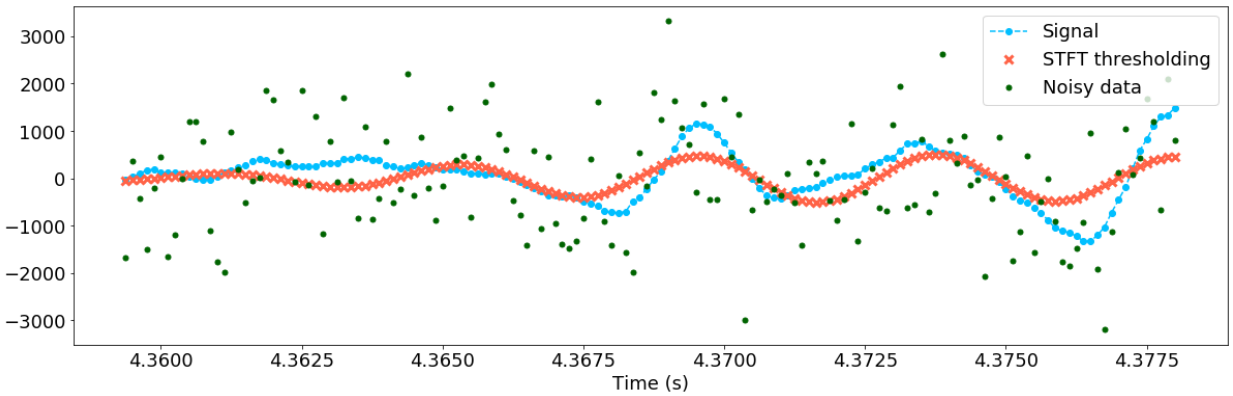
0:06 / 0:06

Block STFT Denoised:

0:02


10000
8000
6000
4000
2000
0
−2000
−4000
−6000
−8000
4.30
4.35
4.40
4.45
4.50
4.55
4.60
4.65
4.70
Time (s)


8000
6000
4000
2000
0
−2000
−4000
−6000
−8000
4.30
4.35
4.40
4.45
4.50
4.55
4.60
4.65
4.70
Time (s)


Signal
STFT thresholding
Noisy data
3000
2000
1000
0
−1000
−2000
−3000
4.3600
4.3625
4.3650
4.3675
4.3700
4.3725
4.3750
4.3775
Time (s)

```
================================================
```

In [ ]: