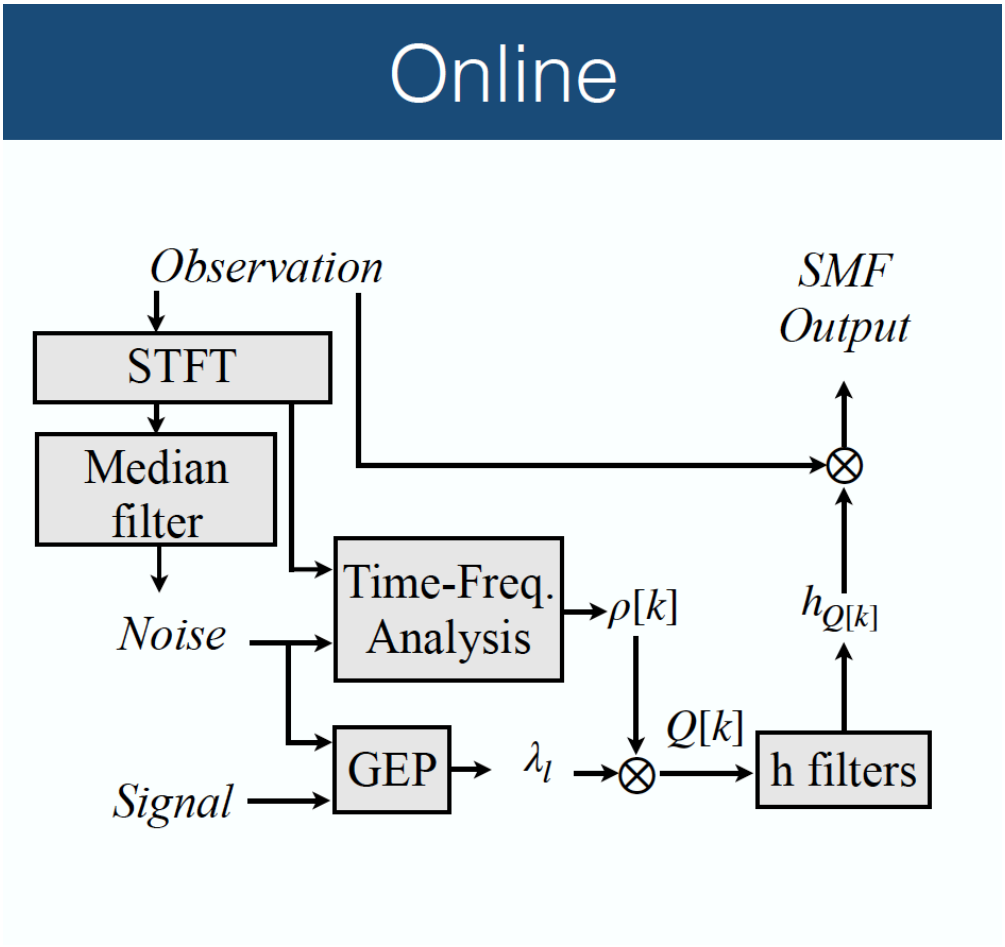
SMF Online application example and comparison to MF

Before to be able to run the online application of the SMF:

1. run *Offline_save_Z-call.m* to simulate the signal and estimate its covariance matrix,
2. run *Offline_save_filterbank.m* to design the filter bank that maximizes the output SNR.

The online application of the SMF executed in this program is illustrated here:



For easy use, required matrices are already saved in the *Offline_saved* folder. A small toy dataset with ABW calls at various SNR is provided (*RR44_2013_D151.wav*). It consists of a 24h record from OBS RR44 deployed during the RHUM-RUM experiment.

```
clearvars
close all
clc

addpath ../Functions
addpath ../Offline_saved
```

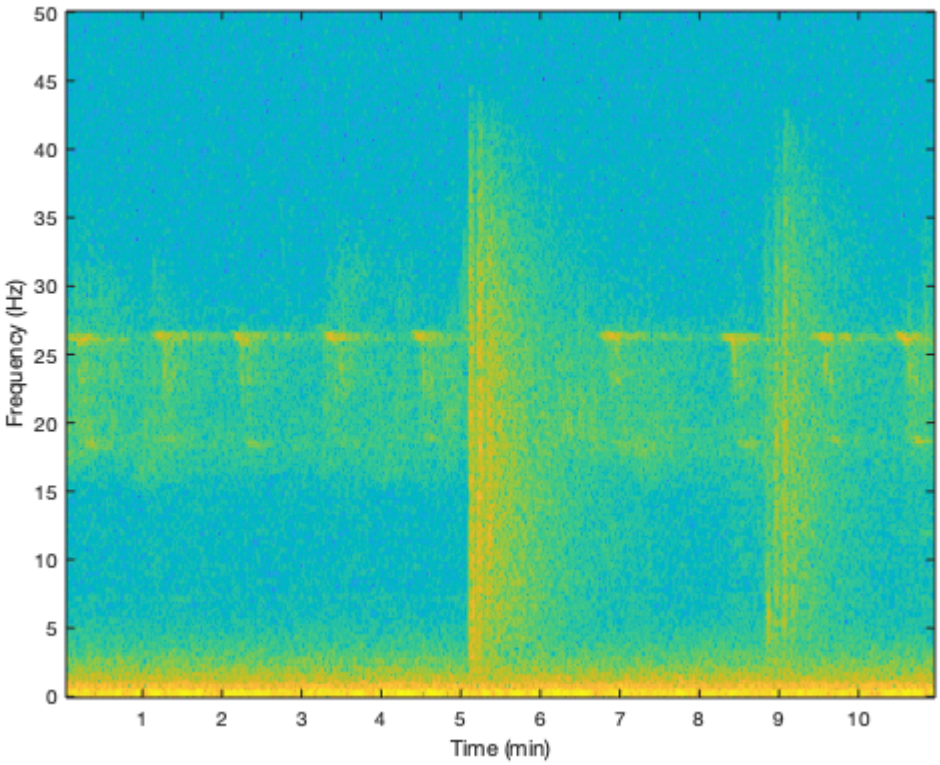
Load signal 10 min starting at 12.34

```
% Load file
name = '../RR44_2013_D151.wav';
```

```
padding =  1; %(min)
duration =  10 + padding; %(min)
begin_time = 12.34;

[x, fs] = cutfile_generalized(name, begin_time, duration);
Tx = (length(x)-1)/fs; % Signal duration (s)
tx = 0:1/fs:Tx; % temporal axis (s)
M = length(x);
```

Spectrogram

```
% Spectrogram parameters
fft_size = 512;
overlap = 98; % \% de recouvrement

[stft,f,t,p] = spectrogram(x/max(x),hann(fft_size),round((overlap/100)*fft_size),fft_si
p = 10*log10(p);

figure
imagesc(t/60,f,p)
axis xy; axis tight;
xlabel('Time (min)');
ylabel('Frequency (Hz)');
set(gca,'clim',[-155 2])
```



Online application of the Stochastic Matched Filter

Loading signal covariance, noise and SNR estimation

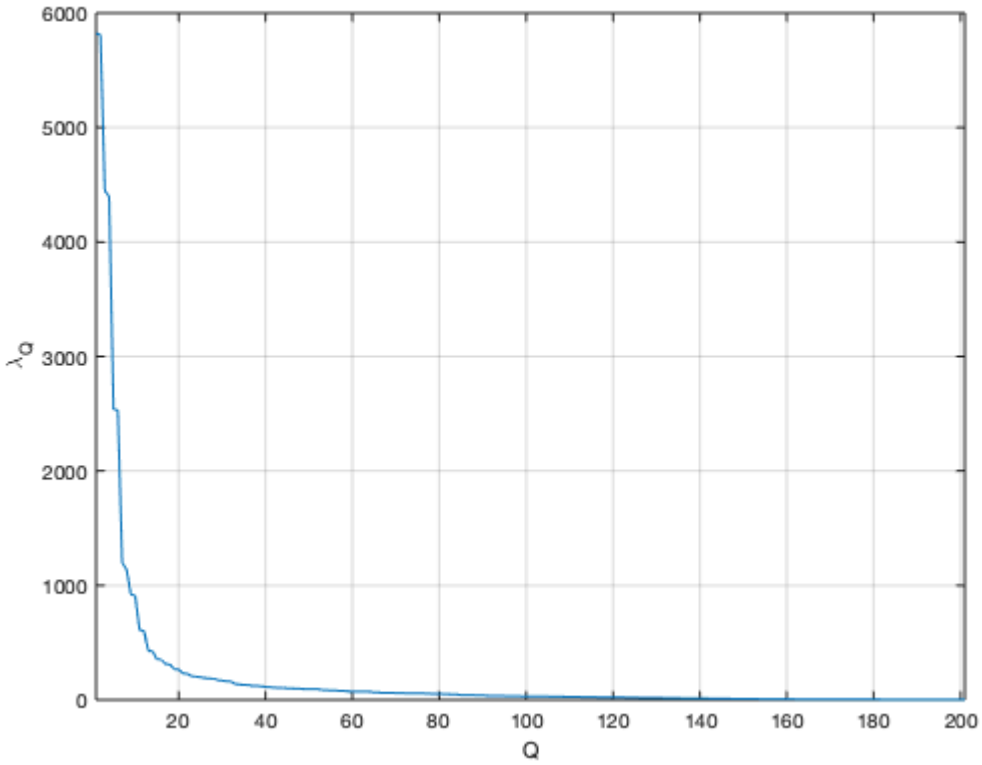
WARNING: The median filter size is set MANUALLY to be about duration of the Z-cal in the TF representation

WARNING: In this function, the SNR is estimated for the Z-call frequency band, if applied to an other signal, change frequency boundary inside the function *zcall_rsb_calc.*

```
% Load signal covariance matrix and eigenvectors
load s_whale.mat ;
N = length(covs);

% Definition of the size of the median filter for background noise
% estimation AND SNR estimation
% The median filter size =~ duration of the Z-cal in the TF representation
med_win_size = 201;

% Observation noise estimation preprocessing + SNR estimation
[covn, Qmax,snr] = SMF_noise_rsb_preprocess_median_phase(x,fs,fft_size,overlap,N,med_wi
```

Generalized Eigenvalue Problem

```
% For Lambda estimation
load('filtre_lambda.mat')

% Limit the max number of filter, Qmax
[~,b] = size(h);
if b < Qmax, Qmax = b; end ; clear a b

% Estimation of the observation's eigenvalues
Lambda_zcall = SMF_GEP_lambda(vecs, covs, covn, Qmax);

figure
plot(1:Qmax,Lambda_zcall)
xlabel('Q'); ylabel('\lambda_Q')
xlim([1 Qmax])
grid on
```



"Real time" application

```
% This is conducted using a sliding window to insure stationarity
% Empty matrix declaration
s = zeros(1,M);
Q = zeros(1,M); % <=> Q !!
z_0  = zeros(1,M+N-1);

% if even or odd
if mod(N,2)==0
    z_0(N/2:end-N/2) = x;
else
    z_0((N+1)/2:end-(N-1)/2) = x;
end

% Application of the SMF filters
for n=1:M
    % Window the observation (we're looking at the center sample)
    zm = z_0(n:n+N-1);

    % Estimation of the number of filters Q to apply to the center sample (n)
    % Q = number of (eigenvalues * snr) > 1 at the discreet time n
    Q(n) = sum((abs(Lambda_zcall)*snr(n))>1);
    % If none are >1, we only take the first filter
    if Q(n)<=0, Q(n)=1; end % Q must be >=1

    % Application of the filter to the observation
```

```
    s(n) = zm*h(:,Q(n)); % Reconstruction du signal
    clear zm
end
```

MF compared to the SMF + MF

Application

```
% reference signal zero-padding
s_0padded = zeros(1,length(x));
s_0padded(1:N) = s_whale ;

% MF on band-pass filtered observation
[b,a]=butter(20,15/(fs/2),'high'); x_filt = filter(b,a,x); % Filtrage des frequences en
[b,a]=butter(30,30/(fs/2),'low'); x_filt = filter(b,a,x_filt); % Filtrage des frequence

CORR_MF_interm = xcorr(x_filt,s_0padded,'coef');
CORR_MF_interm = CORR_MF_interm(M-floor(N/2):end-floor(N/2));
CORR_MF = zeros(1,M);

% SMF + MF
CORR_SMF = zeros(1,M);
CORR_SMF_interm = xcorr(s,s_0padded,'coef');
CORR_SMF_interm = CORR_SMF_interm(M-floor(N/2):end-floor(N/2));

% Correlation max
win_size = 200;
for j = 1 :M - win_size
     CORR_MF(j+floor(win_size/2)) = max( CORR_MF_interm(j:j+win_size));
    CORR_SMF(j+floor(win_size/2)) = max(CORR_SMF_interm(j:j+win_size));
end
```

Remove the 1 minute padding

```
% Spectrogram
debspc = find(t/60>= padding/2,1);
finspc = find(t/60>=duration-padding/2,1);
p = p(:,debspc:finspc);
t = linspace(0,duration,length(p));

% On time vectors
deb = find(tx/60>= padding/2,1);
fin = find(tx/60>=duration-padding/2,1);

Tx_new = Tx - padding*60;
tx_new = (0:1/fs:Tx_new-1/fs)/60;
M = length(tx_new);
s = s(deb:fin);
x = x(deb:fin);
x_filt = x_filt(deb:fin);
snr = snr(deb:fin);
```

```
Q = Q(deb:fin);
CORR_SMF = CORR_SMF(deb:fin);
CORR_MF = CORR_MF(deb:fin);
```

Plot

The call are visually annotated to be displayed on the subplots

```
pres_zcall_time = [0.57 1.55 2.72 3.87 6.17 7.71 8.86 9.89];
corr_shift = 0.22;
pres_zcall_time = pres_zcall_time+0.18;
```

The different subplots are

- (a) Spectrogram
- (b) waveform of the input observation pass-band-filtered between 15 and 30 Hz and, in yellow the signal reconstructed by the SMF
- (c) MF max. when applied to the band-pass observation (the blue waveform of b)
- (d) MF max when applied to the SMF output (the yellow waveform of b)

```
fontsize = 10;
fig = figure;
subplot(4,1,1);
imagesc(t/60,f,p);
axis xy; axis tight; %colormap gray
ylabel('Freq. (Hz)');
title('(a)')
set(gca, 'fontsize', fontsize);

subplot(4,1,2)
plot(tx_new,x_filt/max(x_filt))
hold on
plot(tx_new,(s/max(x_filt)),'Color',[0.9290 0.6940 0.1250])
plot(pres_zcall_time,1.1*ones(size(pres_zcall_time)),'v','Color',[0.8500 0.3250 0.0980]
grid on
ylabel('Ampli. Norm.')
leg1 = legend(' $z_{[15 - 30]Hz}(k)$ ','$\widetilde{s}_{Q[k]}(k)$','Location','South');
set(leg1,'Interpreter','latex');
xlim([0 Tx_new/60])
ylim([-1.3 1.3])
title('(b)') % IN/OUT
set(gca, 'fontsize', fontsize);
box on

subplot(4,1,3)
title('(c)')
hold on
plot(tx_new,(CORR_MF))
plot(pres_zcall_time,corr_shift*ones(size(pres_zcall_time)),'v','Color',[0.8500 0.3250
xlim([0 Tx_new/60]) ; grid on
ylabel('MF')
```

```
set(gca, 'fontsize', fontsize);
ylim([0 0.25])
box on

subplot(4,1,4)
title('(c)')
hold on
plot(tx_new, CORR_SMF)
plot(pres_zcall_time,0.22*ones(size(pres_zcall_time)),'v','Color',[0.8500 0.3250 0.098
xlim([0 Tx_new/60]) ; grid on
xlabel('Time (min)')
ylabel('SMF + MF')
hold on
ylim([0 0.25])
set(gca, 'fontsize', fontsize);
box on

subplot(4,1,2)
xlim([0.00 10.00])
ylim([-1.3 1.3])
legend({'$z_{[15 - 30]Hz}(k)$','$\widetilde{s}_{Q[k]}(k)$'},'Location','south')
```