# Project 3 - Spectral Estimation

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# Spectral estimation

# Exercise 1 A - Data selection

- Channel 14
- Start sample $M = 1200$
- Number of samples $N = 1024$

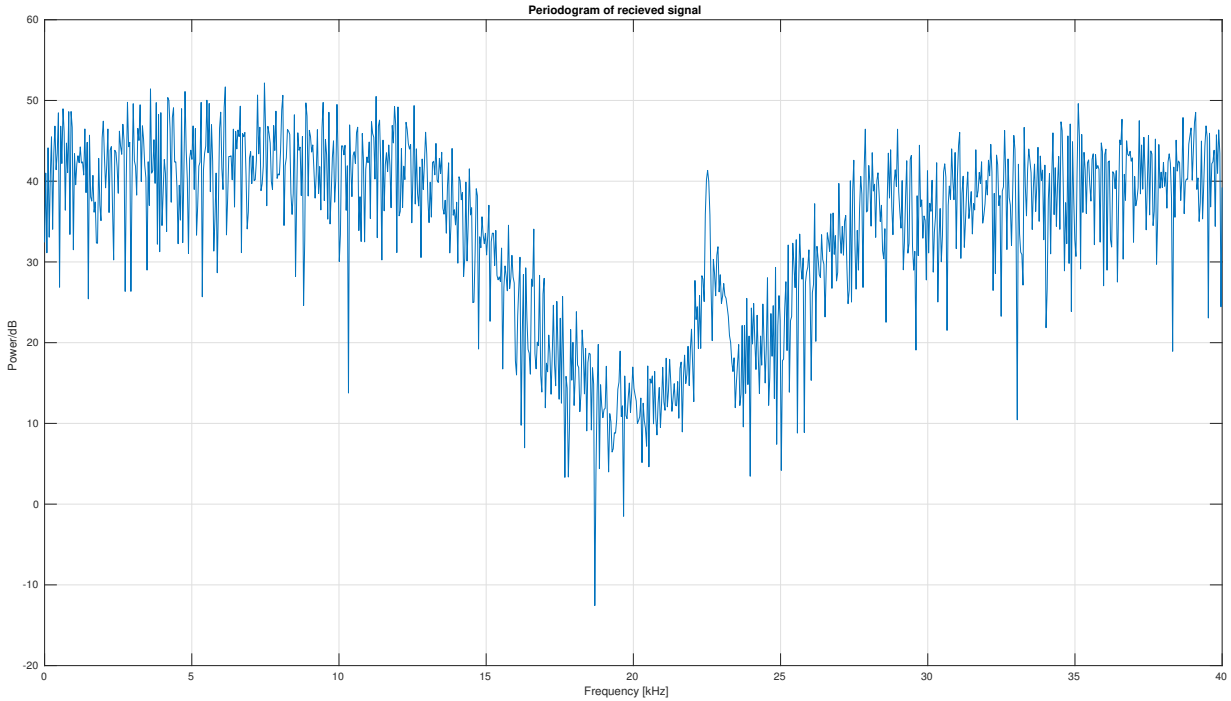


**Figure 1:** Periodogram

# Exercise 1 A - The modified periodogram with a window

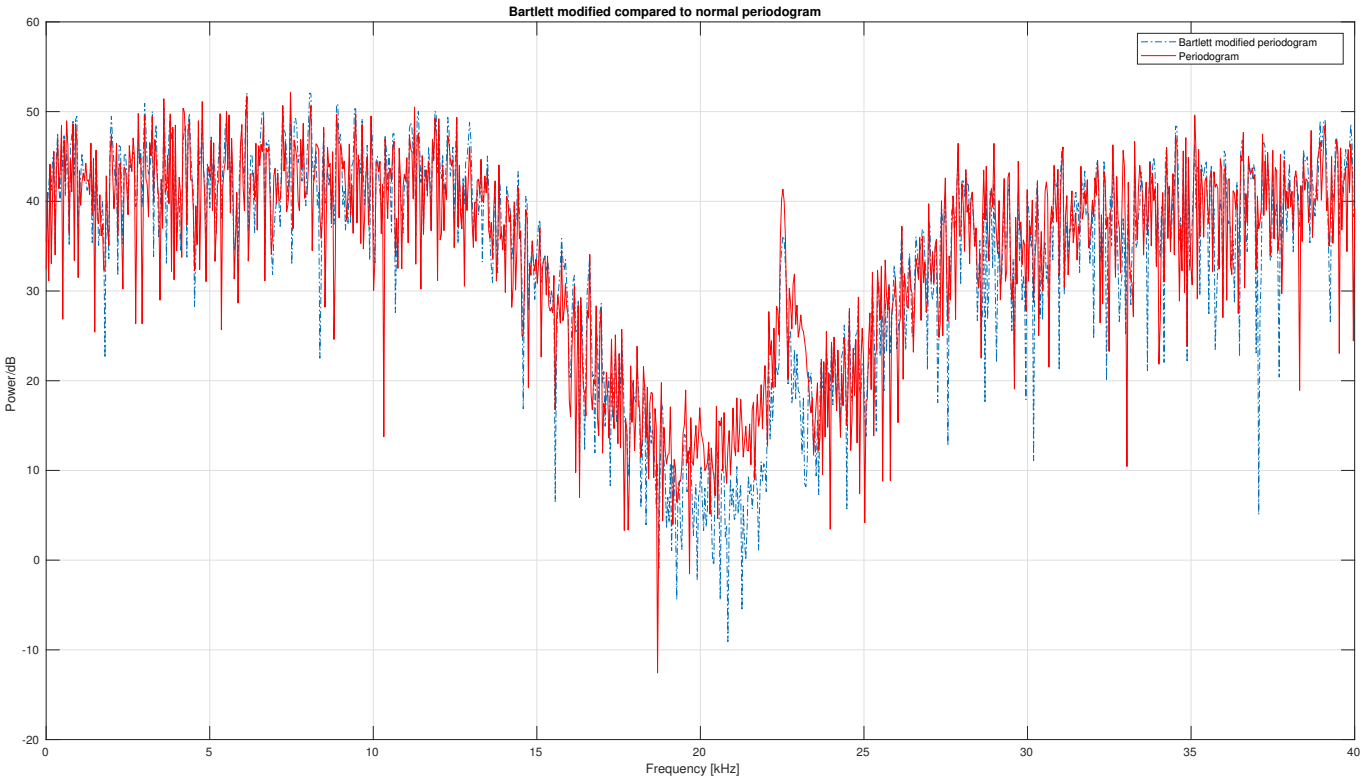


**Figure 2:** Modified periodogram with bartlett window

# Exercise 1 A - The modified periodogram with a window

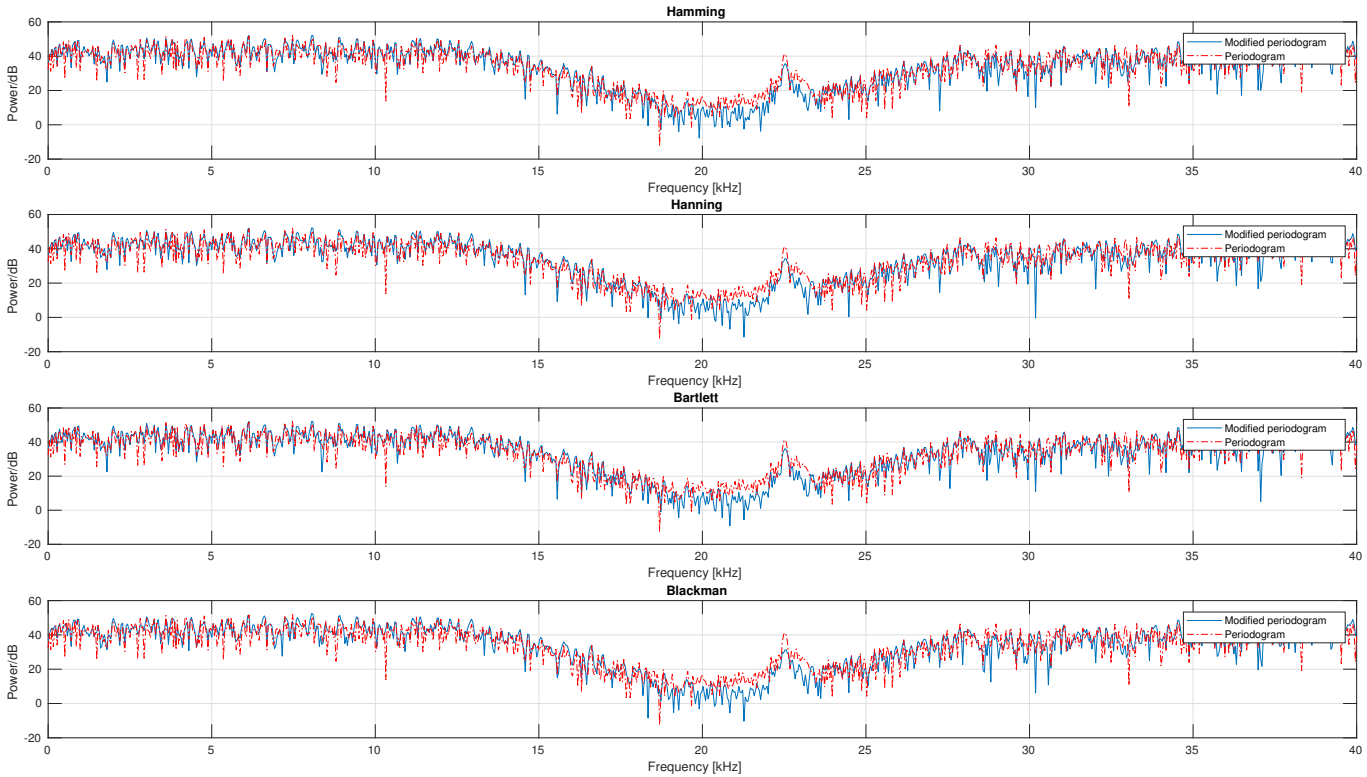


**Figure 3:** All modified periodograms with window

# Exercise 1 A - The Welch method

L = 256, overlap D = L/2

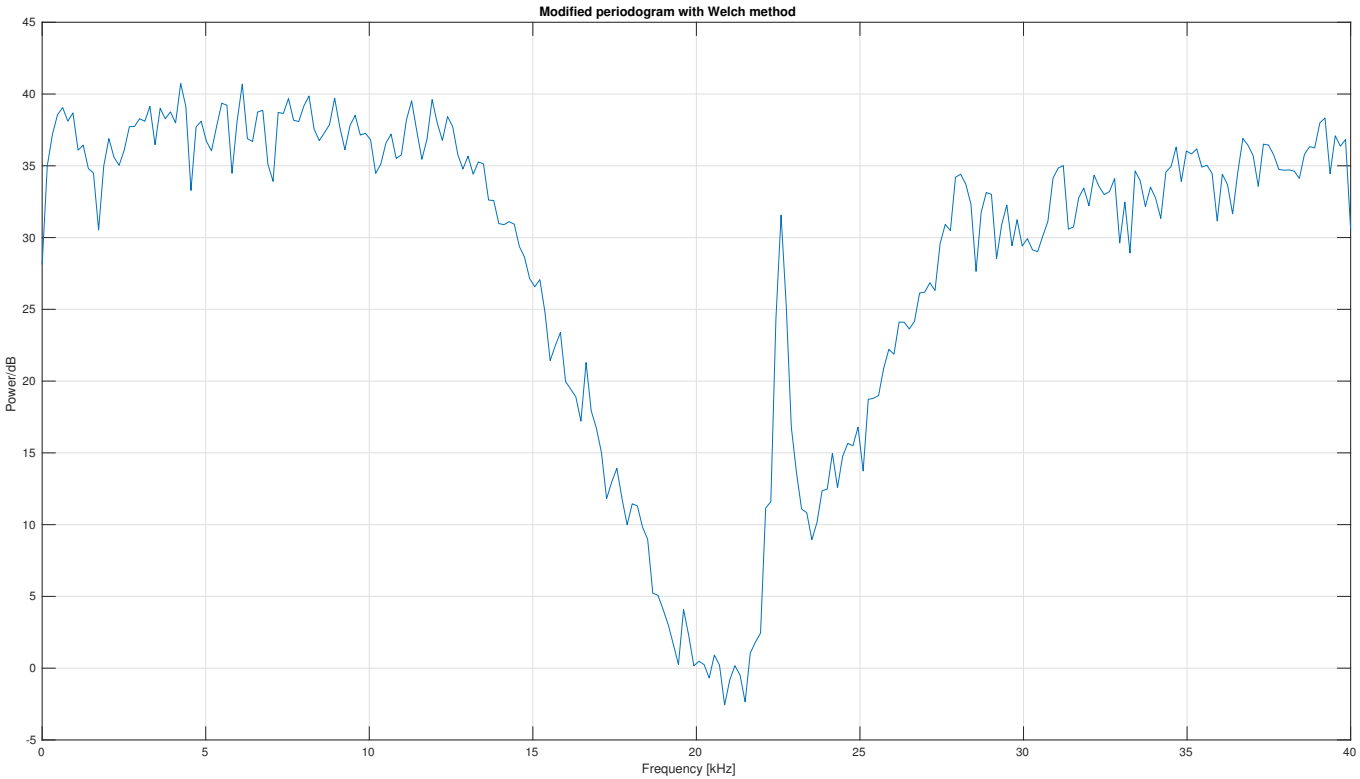


**Figure 4:** Welch method

# Exercise 1 A - The multitaper spectral estimation

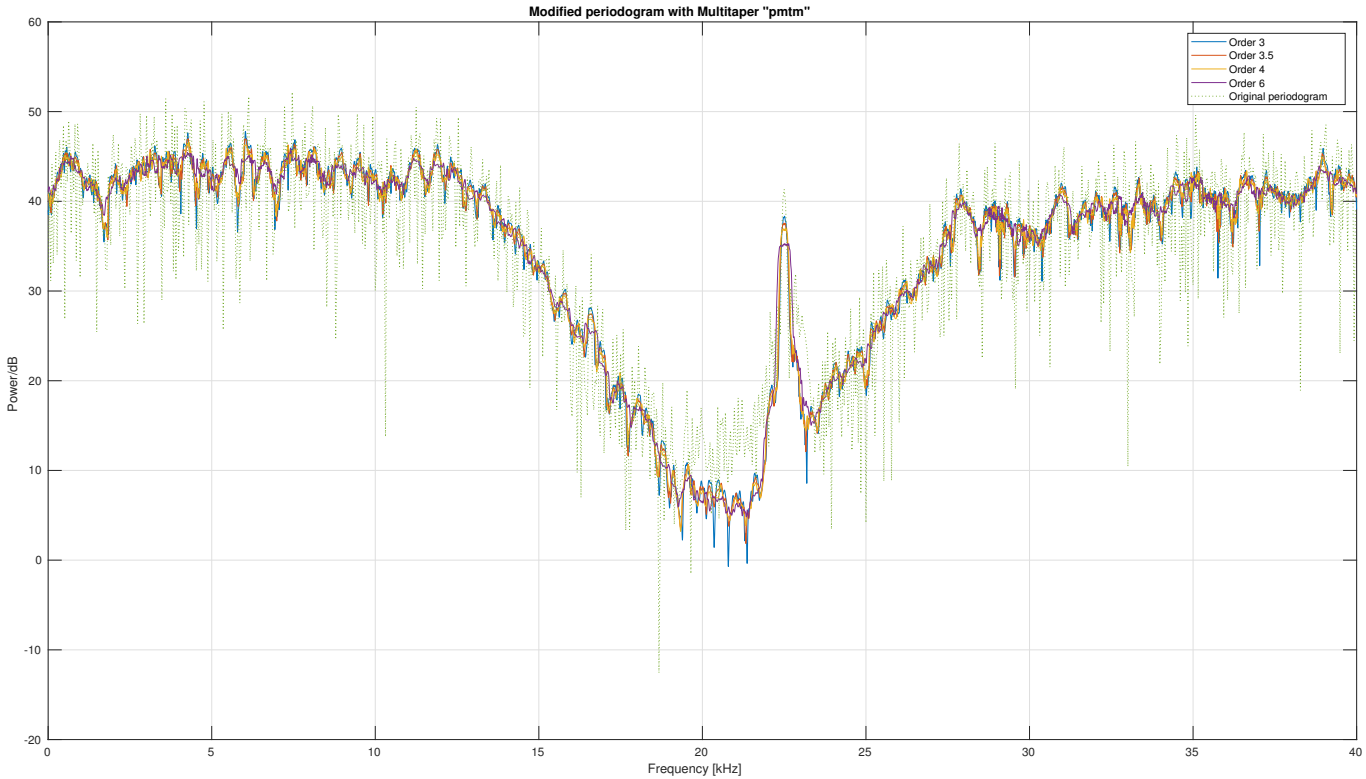


**Figure 5:** Multitaper "pmtm" with orders 3, 3.5, 4 and 6

# Does bias reduction help?

- Hard to see bias reduction due data not being averaged or a model
- No estimate of true signal, cannot see what the spectral estimate is approaching
- Known fact, is lower side lobes, gives better bias reduction.
- Choosing Blackman or Chebyshev window, gives best bias reduction
- May add more variance to signal

# Does variance reduction help?

- Looking at data, the variance is slightly reduced with modified periodogram
- Variance being smeared out due to convolution with side lobes.
- Variance reduction works, more with multitapering.
- Variance reduction is a trade-off with spectral resolution

# Exercise 1 B - Data selection

- Channel 9
- Start sample $M = 7000$
- Number of samples $N = 2048$

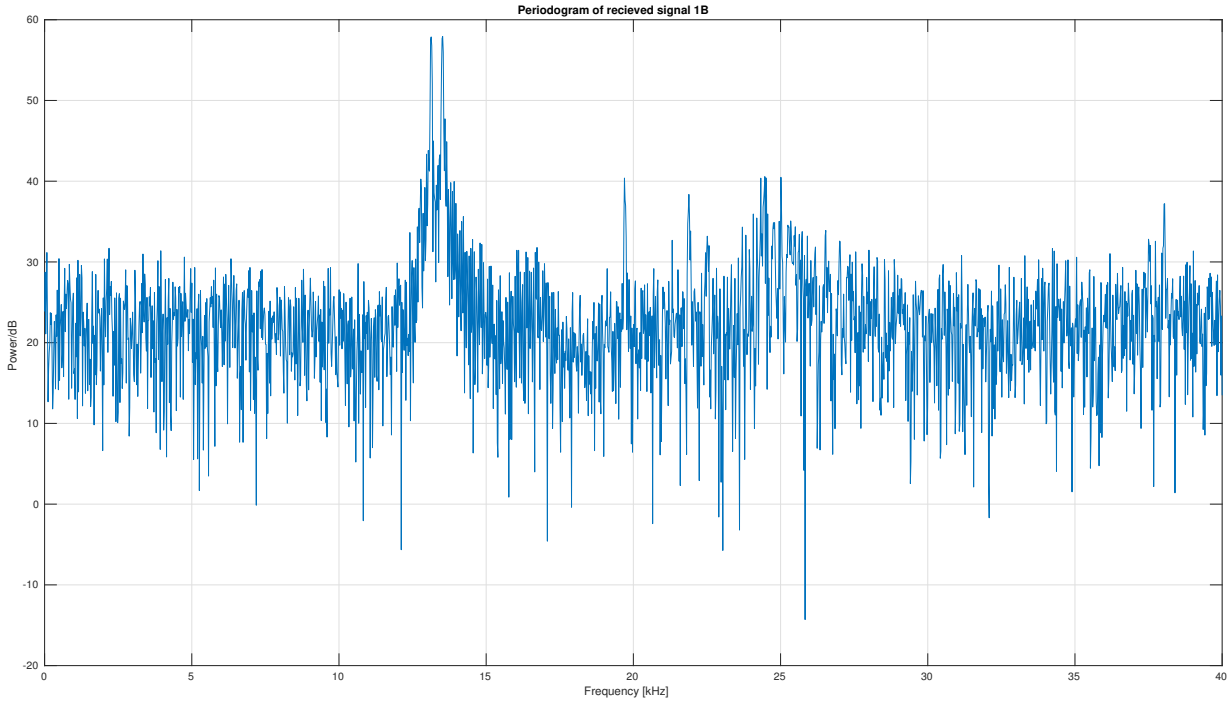


**Figure 6:** Periodogram

# Exercise 1 B - The modified periodogram with a window

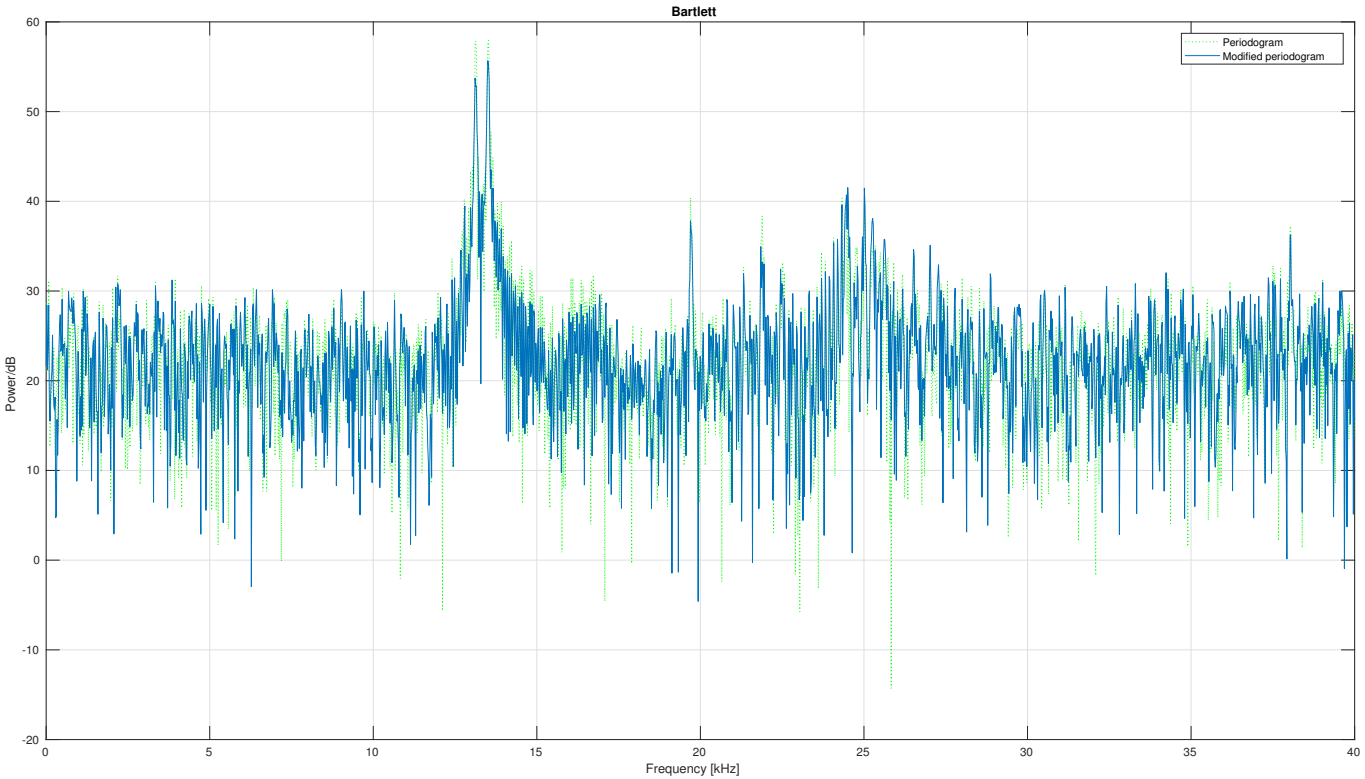


**Figure 7:** Modified periodogram with bartlett window

# Exercise 1 B - The Welch method

L = 256, overlap D = L/2

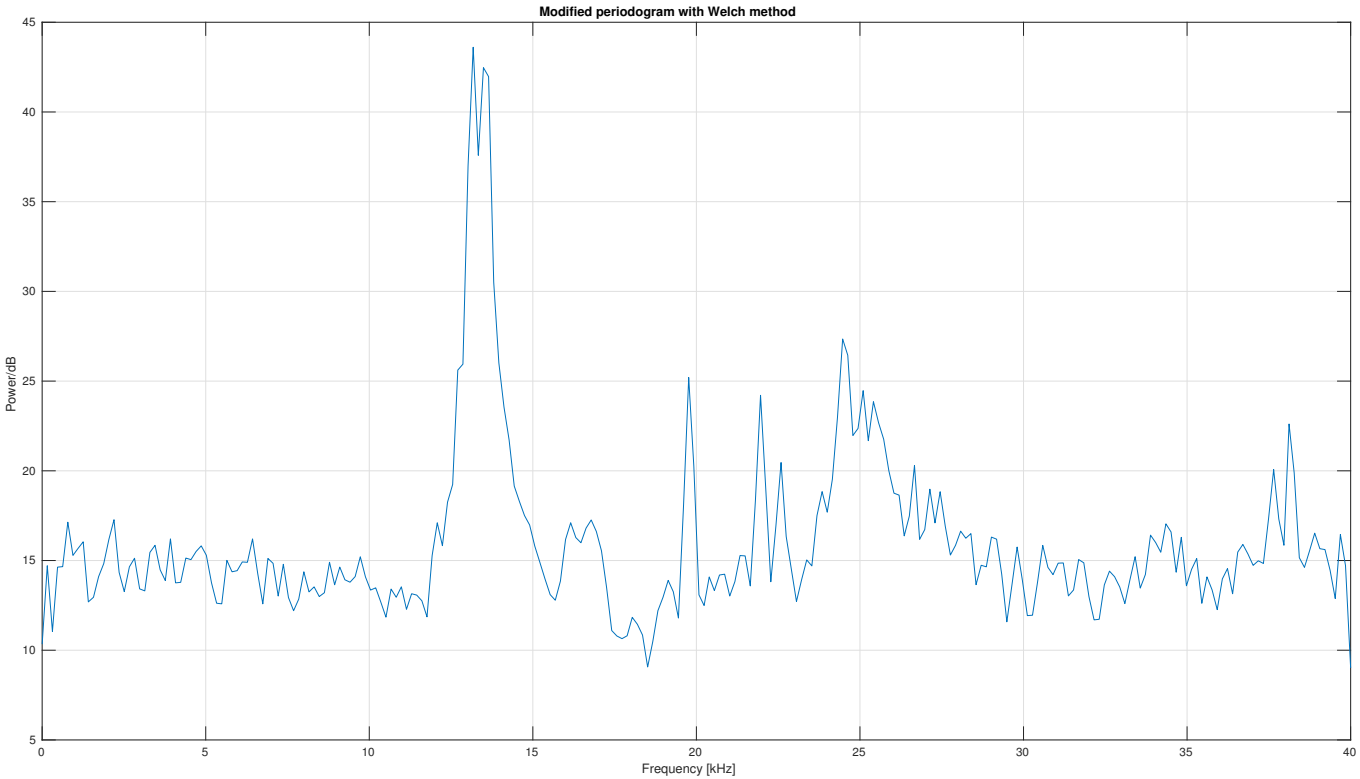


**Figure 8:** Welch method

# Exercise 1 B - The multitaper spectral estimation

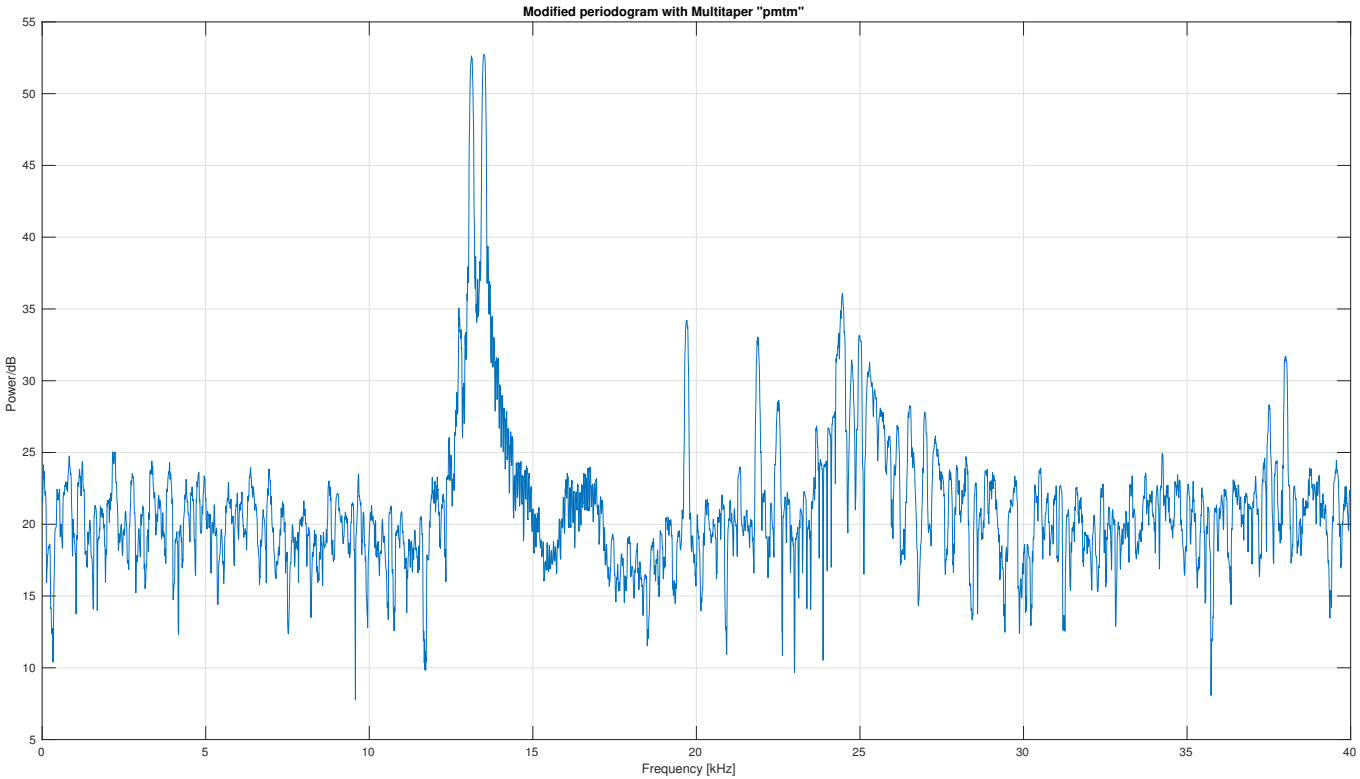


**Figure 9:** Multitaper "pmtm" with orders 3, 3.5, 4 and 6

# Exercise 1 B - Does bias reduction help?

1 B bias

# Exercise 1 B - Does variance reduction help?

- Same as in exercise 1 A
- Welch method and multitaper reduces variance alot
- Trade-off with spectral resolution

What is the concequence of variance reduction? We are loosing spectral resolution in the periodogram when reducing variance

# Spectrogram analysis

# Exercise 2 A - Data selection

- Channel 14
- Start sample $M = 400$
- Number of samples $N = 8192$

# Exercise 2 A - Modified periodogram with taperwindow

Choosing to keep using Bartlett tapering

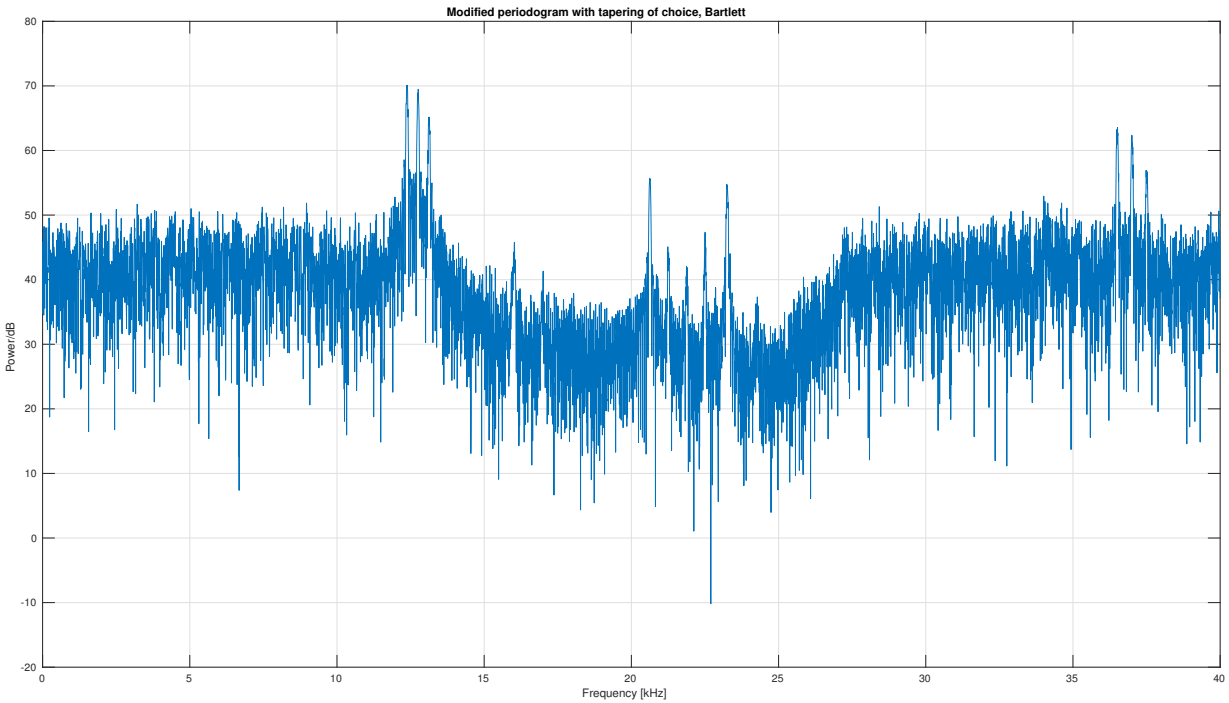


**Figure 10:** The modified periodogram for STFT

# Exercise 2 A - Different segment lengths, L=64,128,256,512

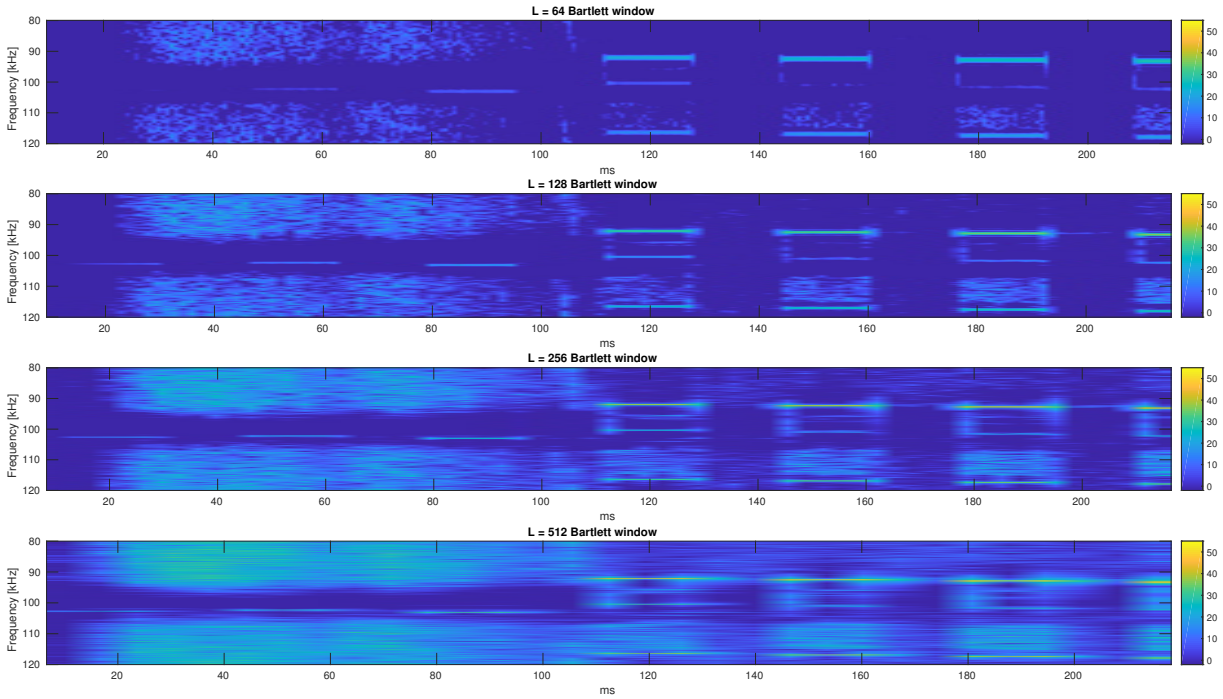


**Figure 11:** Short-time Fourier transform

# Exercise 2 A - Matlab-code for STFT

```
function stfft = stft(x, L, D, win, fac)
    ol = D/L; n1 = 1; n0 = (1-ol)*L;
    nsec = floor((length(x) - L)/n0) + 1;
    stfft = zeros(L*fac, nsec);
    if (ol >= 1) | (ol < 0)
        error('Overlap is invalid');
    end

    for i = 1:nsec
        [Pxx_hat, ~] = modper(x, win, fac, n1, n1+L-1);
        stfft(:,i) = Pxx_hat(1:end)/nsec;
        n1 = n1 + n0;
    end
end
```

# Exercise 2 A - Matlab-code for modified periodogram

```
% Modified periodogram
function [Pxx_hat, axis] = modper(x, win, fac, n1, n2)
    load('data/sonardata4.mat');
    x = x(:);
    if nargin == 3
        n1 = 1;
        n2 = length(x);
    end
    L = n2 - n1 + 1;
    w = ones(L, 1);
    if (win == 1); w = hamming(L);
    elseif (win == 2); w = hanning(L);
    elseif (win == 3); w = bartlett(L);
    elseif (win == 4); w = blackman(L);
    end
    wx = x(n1:n2).*w/norm(w);
    Pxx_hat = L*per(wx, fs, fac);
    axis = linspace(0,fs/1000,L);
end
```

# Exercise 2 A - Matlab-code for periodogram

```
% Periodogram

function Pxx_hat = per(x, fs, fac)
    X = fft(x, length(x)*fac);
    N = length(X);
    X(2:N-1) = X(2:N-1).*2;
    Pxx_hat = ((abs(X).^2)).*(2/fs); % Remember to use 10*
    log10 in plot because we square it here
end
```

# Exercise 2 A - What is the concequence of choosing segment length?

- Choosing longer segment lengths, reduced resolution in the frequency domain
- Trade-off between time domain and frequency domain
- Longer segment lengths, better time domain resolution
- Shorter segment length, better frequency domain resolution

This trade-off can also be seen in figure 11.

# Exercise 2 A - Length of other chips, are the frequencies constant from chip to chip?

The chips seen around the time-frequency representation (especially from 100 ms to 200 ms, are from other interfering sensors. What is the length of the chips (in ms)? Are the frequencies constant from chip to chip?

By inspection, the chips seem to be 14-16 milliseconds long. They also seem to have a constant length.

# Questions?