*CONFIDENTIAL DOCUMENT*

# Report about Pwelch

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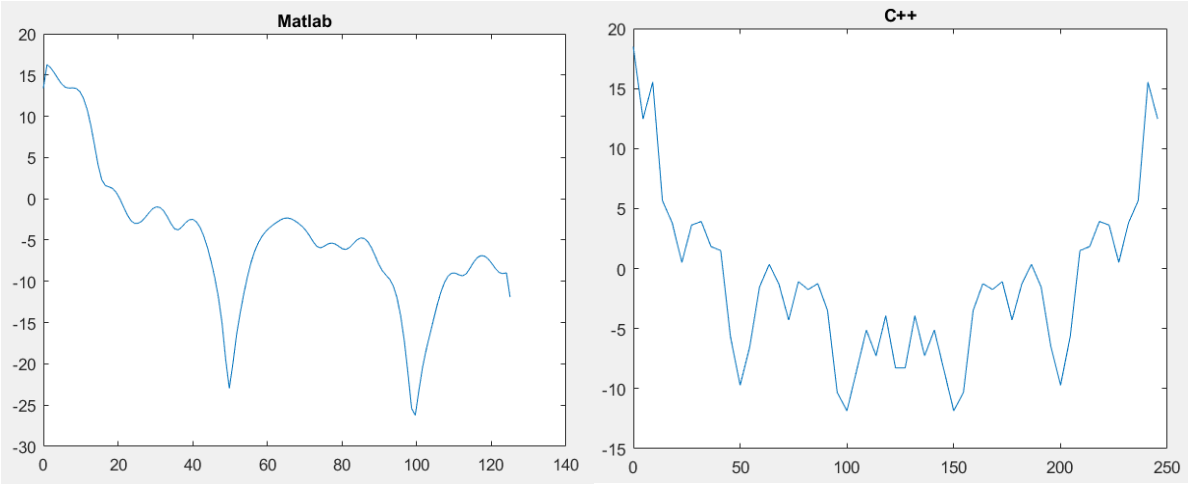
|---|---|
| History of modifications:<br><br>- *Creation 20/01/2017* : Fanny Grosselin<br>Description of the changes in MBT_PWelchComputer and MBT_Fourier in order to have the same results than with the pwelch of Matlab.<br>- Update on 03/02/2017 : Fanny Grosselin | |

## *Introduction :*

This document lists and describes the changes induces in MBT_PWelchComputer and MBT_Fourier in order to converge to the same result than with pwelch of Matlab.

## 1. Comparison of the psd with a signal with 250 datapoints.

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
initial MBT_PWelchComputer and initial MBT_Fourier




Size of frequency vector : 1x129 (from 0 to 125Hz) 1x55 (from 0 to 245,45Hz)

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
First change of MBT_PWelchComputer and initial MBT_Fourier

**First change of MBT_PWelchComputer.cpp:**

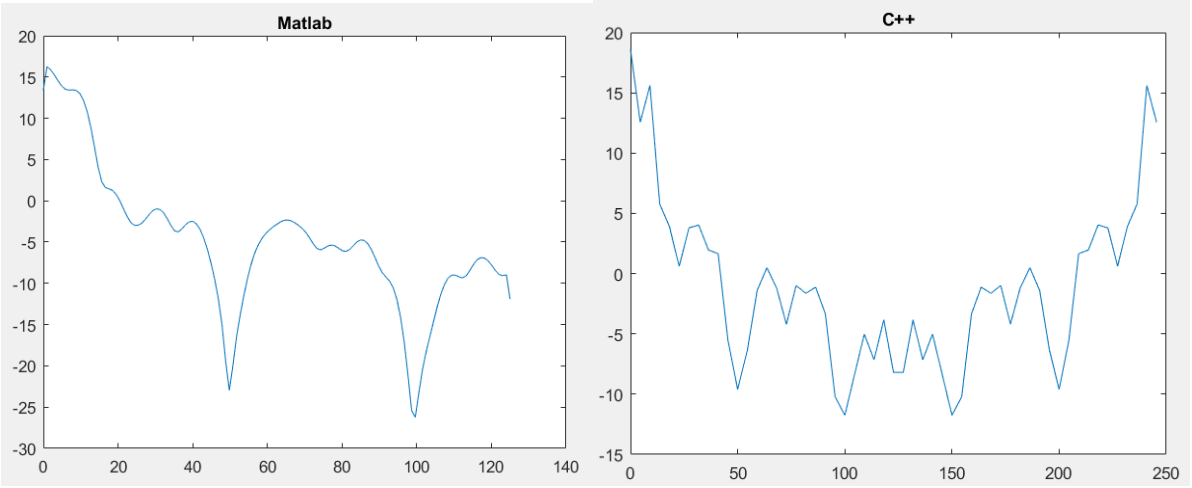
```
const float  PI_F=3.14159265358979f;
    switch (m_windowType) {
        case RECT:
            return 1;
            break;

        case HANN:
           //return (1.0 - cos(2.0 * PI_F * n / windowLength)) / 2.0;
            return (1.0 - cos(2.0 * PI_F * n / (windowLength-1))) / 2.0; // Fanny Grosselin
2017/01/10 (windowLength-1) instead of windowLength
            break;

        case HAMMING:
           //return 0.54 - 0.46 * cos(2.0 * PI_F * n / windowLength);
            return 0.54 - 0.46 * cos(2.0 * PI_F * n / (windowLength-1));   // Fanny Grosselin
2017/01/10 (windowLength-1) instead of windowLength
            break;

        default:
            break;
    }
```

**Explainations:**

w = hamming(L) returns an L-point symmetric Hamming window in the column vector w. L should be a positive integer. The coefficients of a Hamming window are computed from the following equation.

$$w(n) = 0.54 - 0.46 \cos\left(2\pi \frac{n}{N}\right), \quad 0 \le n \le N$$

The window length is L=N+1.

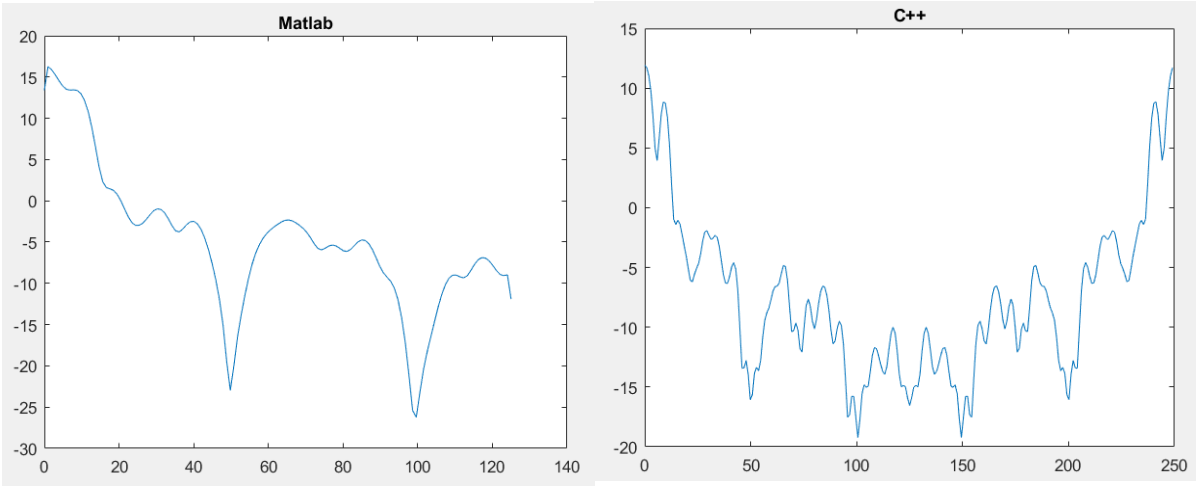



Size of frequency vector : 1x129 (from 0 to 125Hz) 1x55 (from 0 to 245,45Hz)

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Second change of MBT_PWelchComputer and initial MBT_Fourier

**Second change of MBT_PWelchComputer.cpp:**

```
Zero-padding of each segment.
```




Size of frequency vector : 1x129 (from 0 to 125Hz) 1x256 (from 0 to 245,45Hz)

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Second change of MBT_PWelchComputer and First change of MBT_Fourier

**First change of MBT_Fourier.cpp:**

```
Change ceil to floor in the computation of powerOfTwoLength in
MBT_FourierBluestein::bluesteinConvolutionParallel.
```

No change concerning the plot.

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Second change of MBT_PWelchComputer and Second change of MBT_Fourier

**Second change of MBT_Fourier.cpp:**

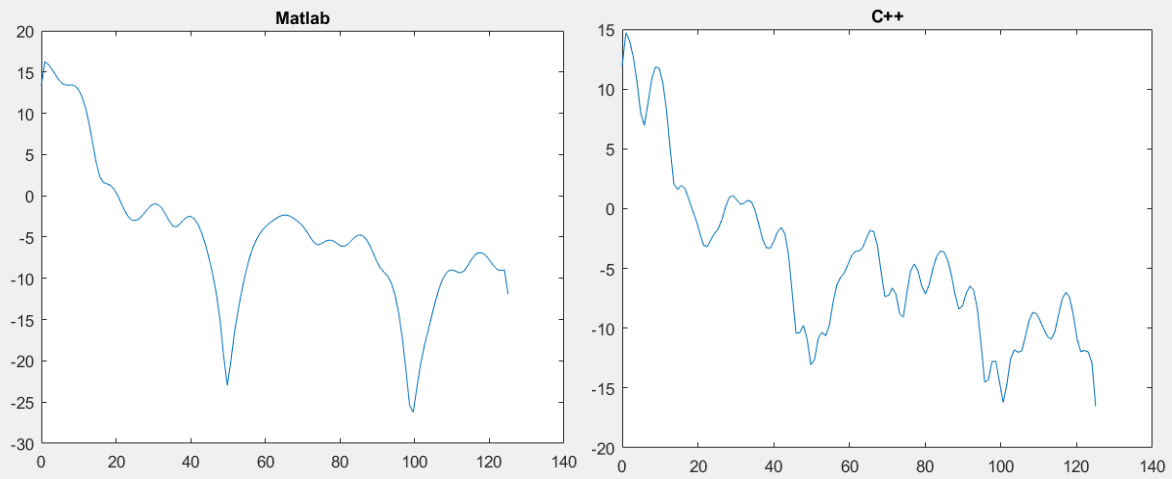
```
Zero-padding instead of padding by the mirror of the signal in
MBT_FourierBluestein::workerBluesteinConvolutionParallelB and
MBT_FourierBluestein::bluesteinConvolutionParallel
```

No change concerning the plot.

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Third change of MBT_PWelchComputer and Second change of MBT_Fourier

**Third change of MBT_PWelchComputer.cpp:**

```
Compute the one-sided spectrum.
```

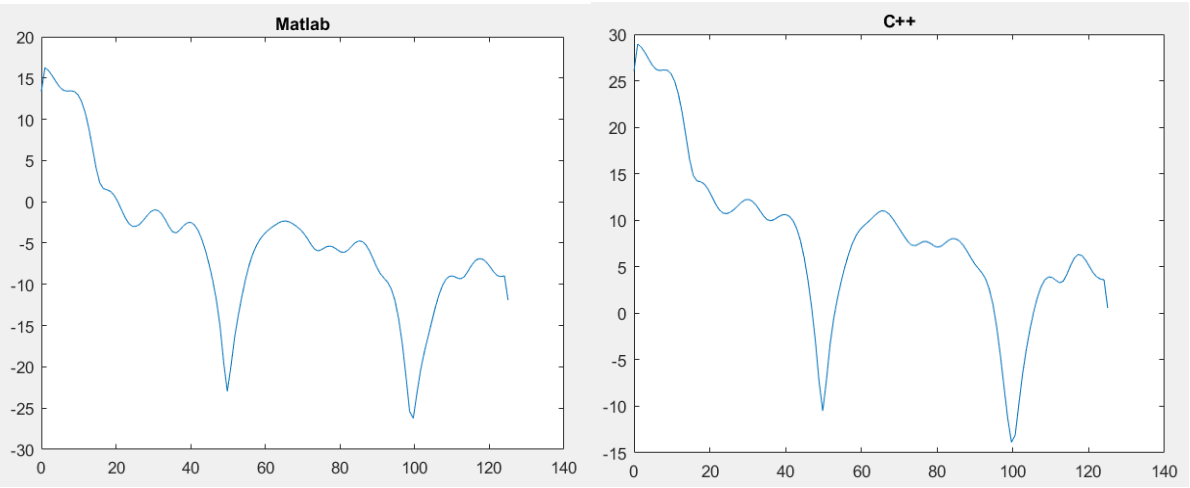



Same frequency vector : 1x129 (from 0 to 125Hz)

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Fourth change of MBT_PWelchComputer and Second change of MBT_Fourier

**Fourth change of MBT_PWelchComputer.cpp:**

```
Correct the complexSignal generation: computeWindow should be called with i and not window
because "n" of computeWindow should be in [0:windowLength-1] and not in [0:windowNumber].
```

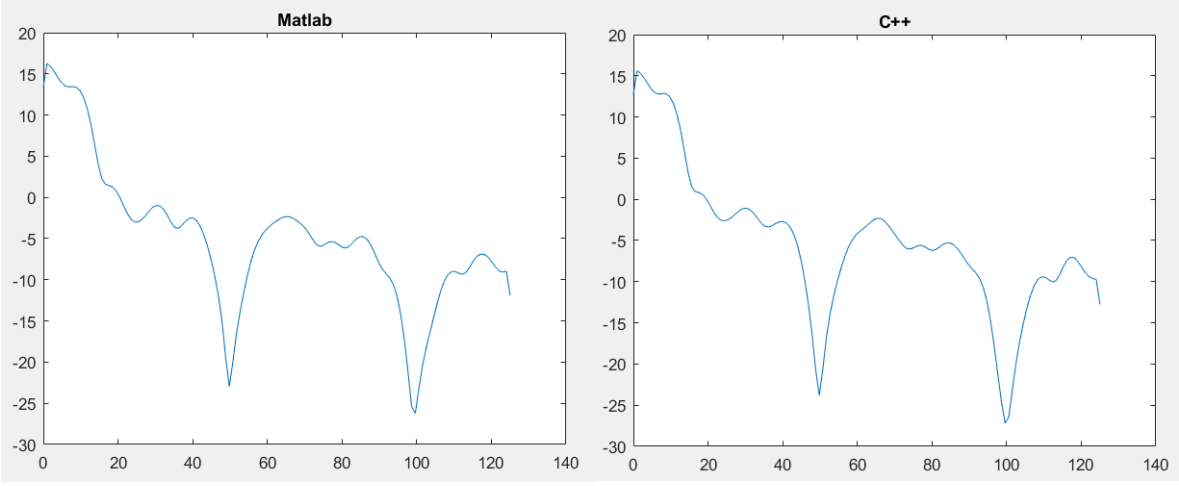



Same frequency vector : 1x129 (from 0 to 125Hz)

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Fifth change of MBT_PWelchComputer and Second change of MBT_Fourier

**Fifth change of MBT_PWelchComputer.cpp:**

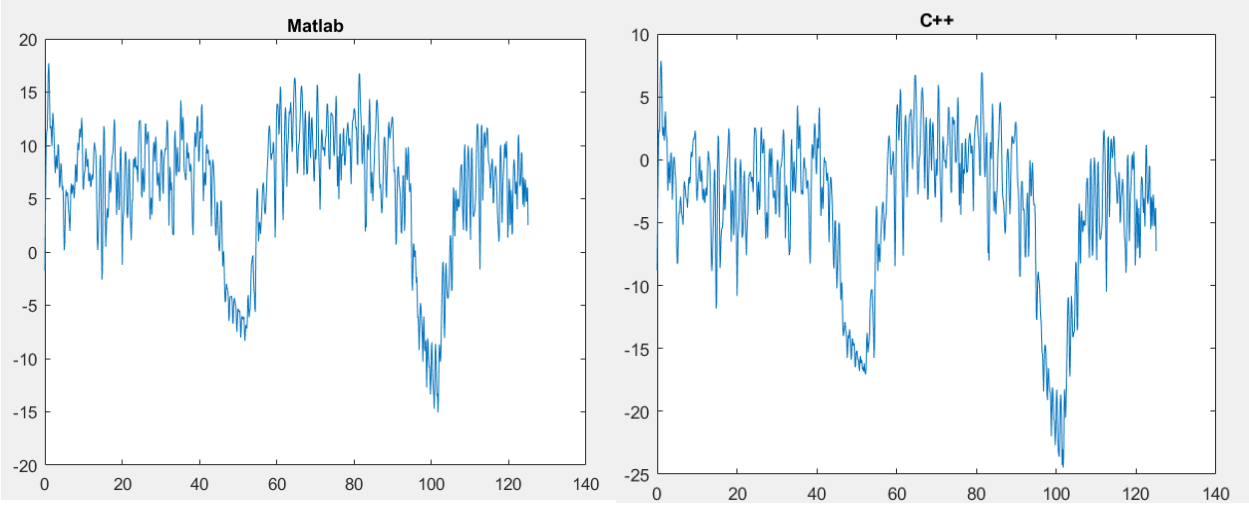
```
Compensate the power of the Hamming window by dividing the power by the power of the window.
```




Same frequency vector : 1x129 (from 0 to 125Hz)

## 2. Comparison of the psd with a signal with 5000 datapoints.

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Fifth change of MBT_PWelchComputer and Second change of MBT_Fourier

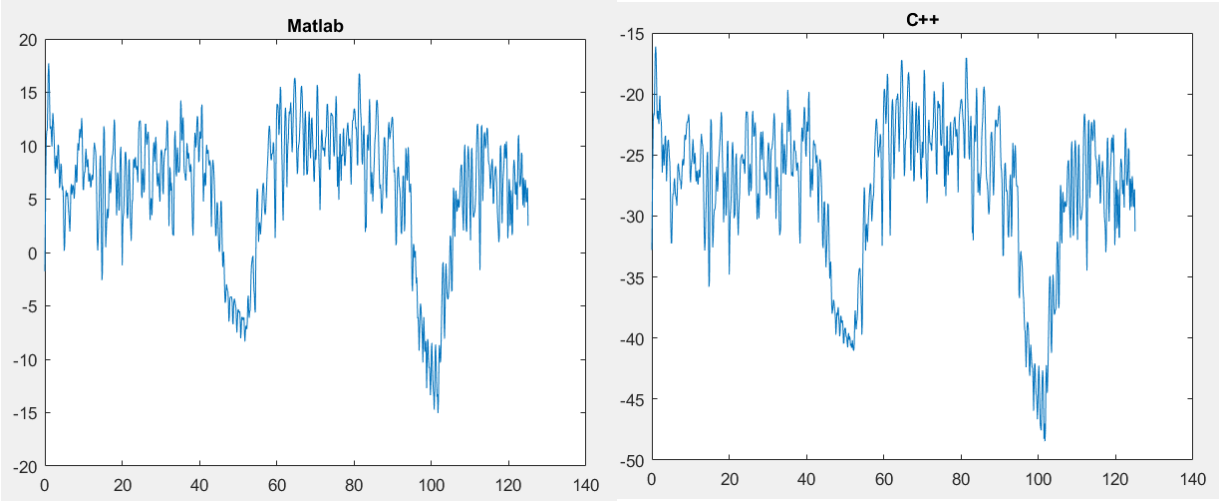



Same frequency vector : 1x1025 (from 0 to 125Hz)

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Sixth change of MBT_PWelchComputer and Second change of MBT_Fourier

**Sixth change of MBT_PWelchComputer.cpp:**

```
Divide the power by samplingRate like in Matlab.
```

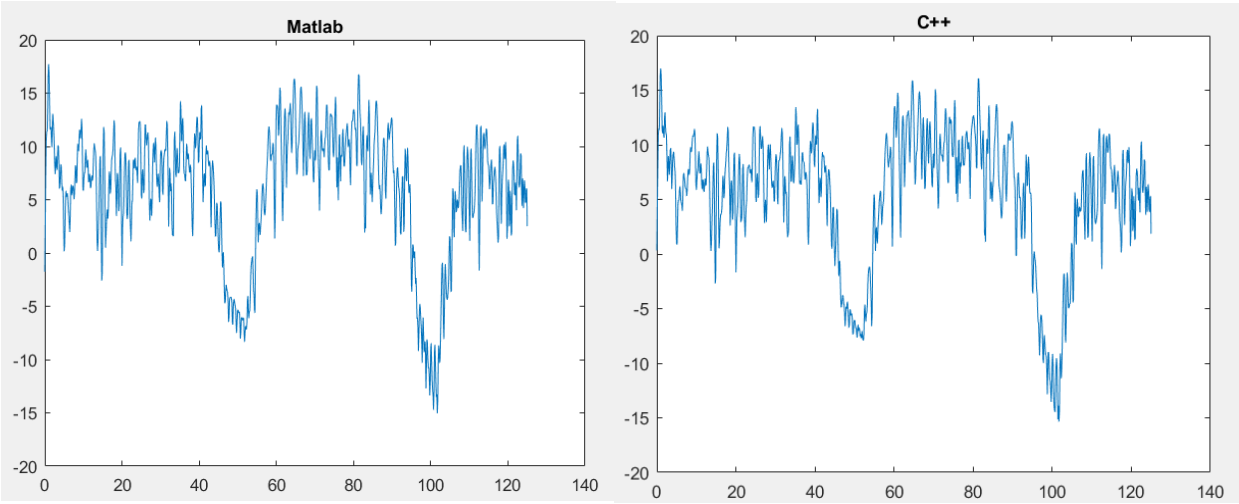



Same frequency vector : 1x1025 (from 0 to 125Hz)

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Seventh change of MBT_PWelchComputer and Second change of MBT_Fourier

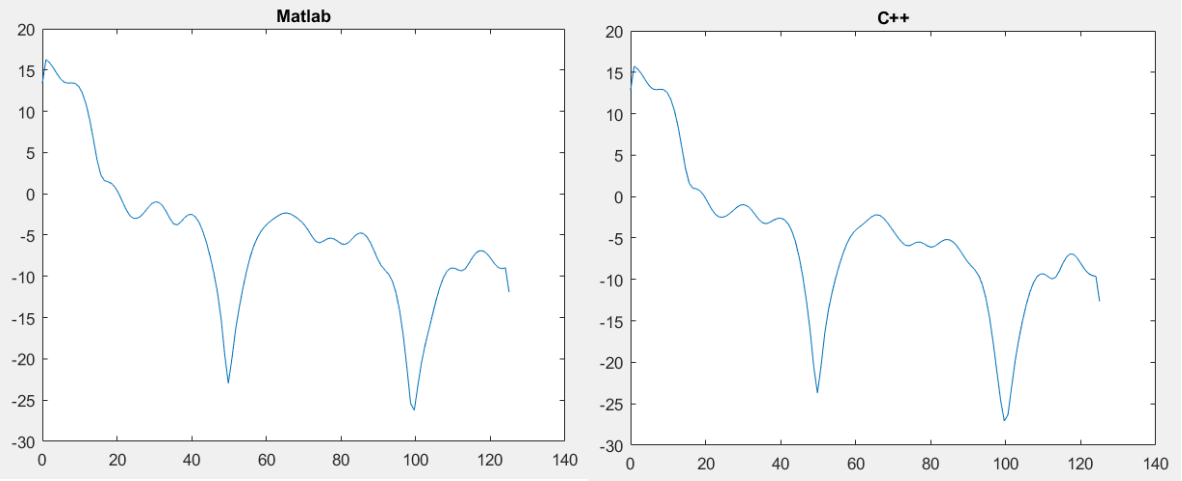
**Seventh change of MBT_PWelchComputer.cpp:**

Add a new method to compute fft and use it instead of MBT_Fourier::forwardBluesteinFFT.
This new nethod was found here: http://stackoverflow.com/questions/10121574/safe-and-fast-fft



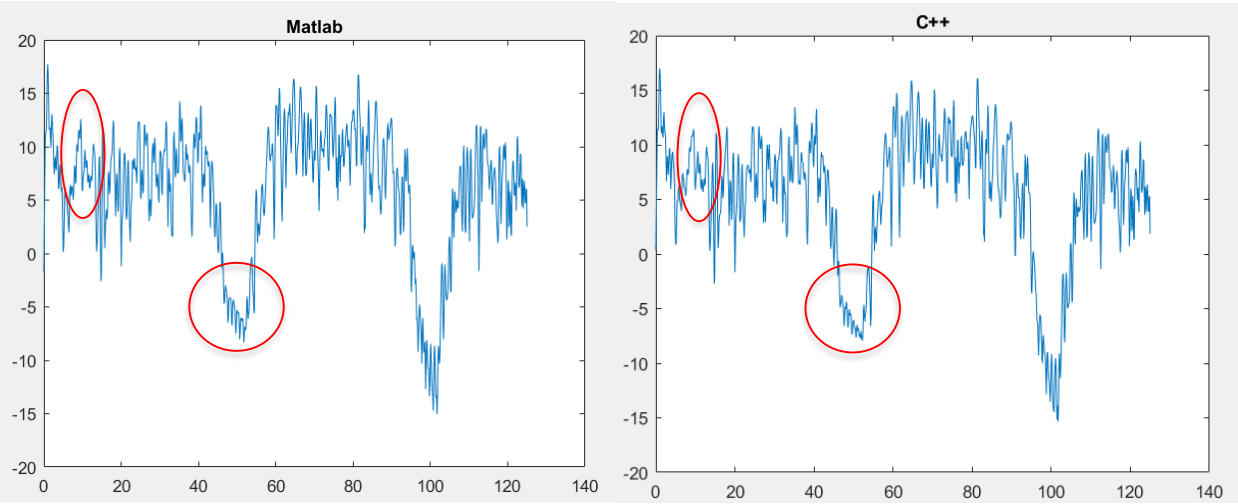

Same frequency vector : 1x1025 (from 0 to 125Hz)

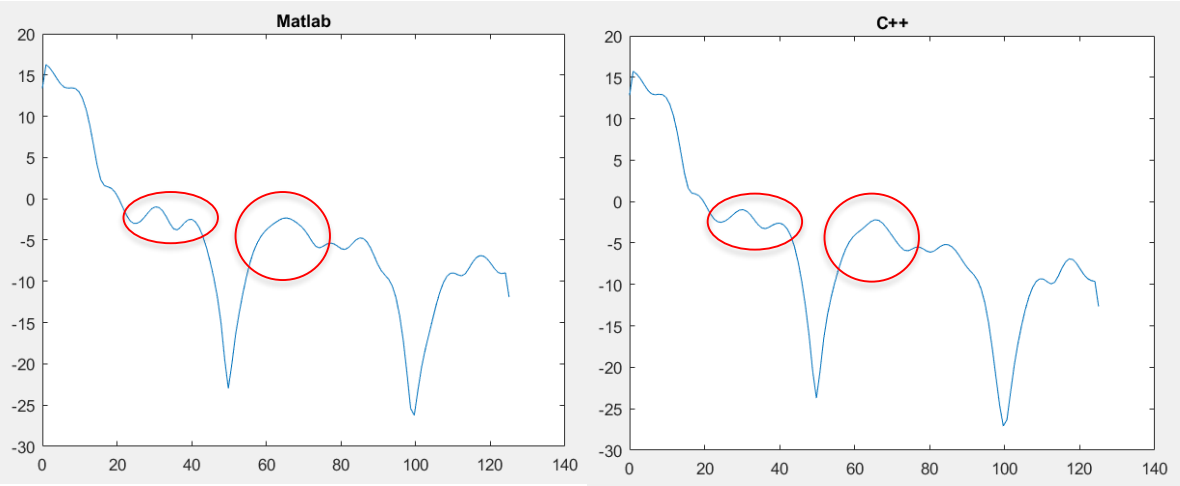
For a signal of 250 datapoints:




Conclusion: almost the same trend at the same level but not exactly exactly the same values.

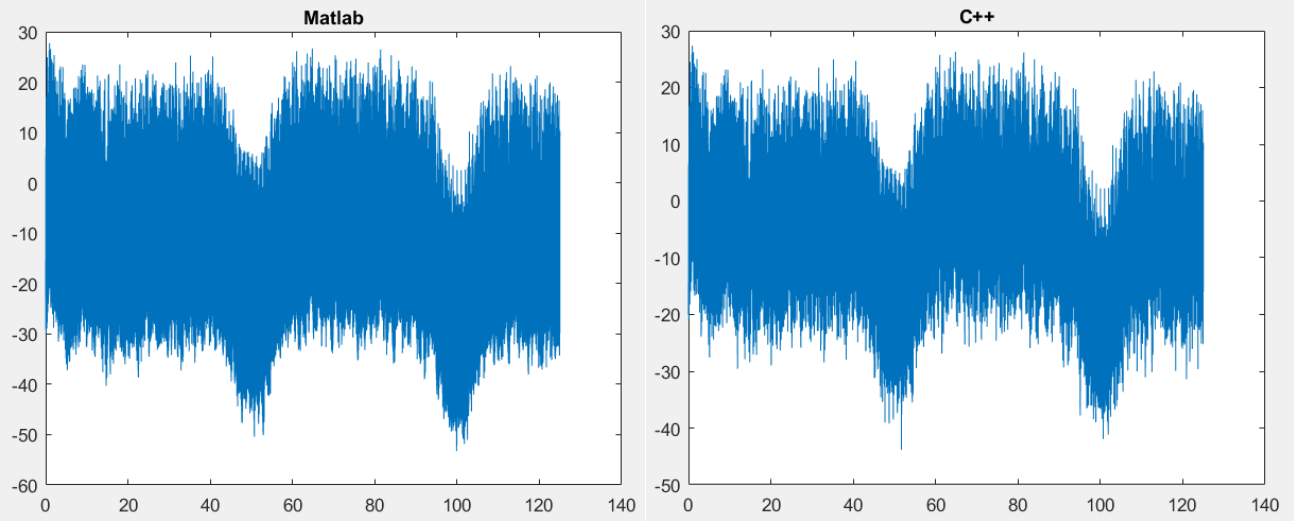
See below the little differences:



## 3. Comparison of the psd with a signal with 160000 datapoints.

160000 datapoints ~ 10.667min




Same frequency vector : 1x32769(from 0 to 125Hz)

In C++, a such signal need 213,856s = 3.56min to compute fft…

## 4. Adjustement of MBT_Fourier to have the same result than with fft

.

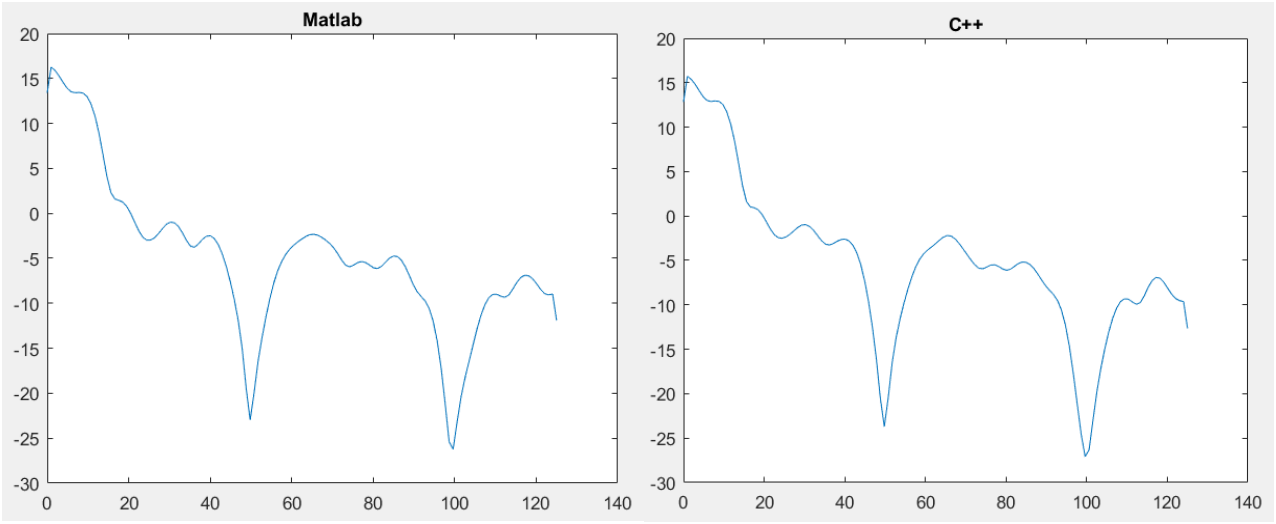
[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Seventh change of MBT_PWelchComputer and Third change of MBT_Fourier

**Third change of MBT_Fourier.cpp:**

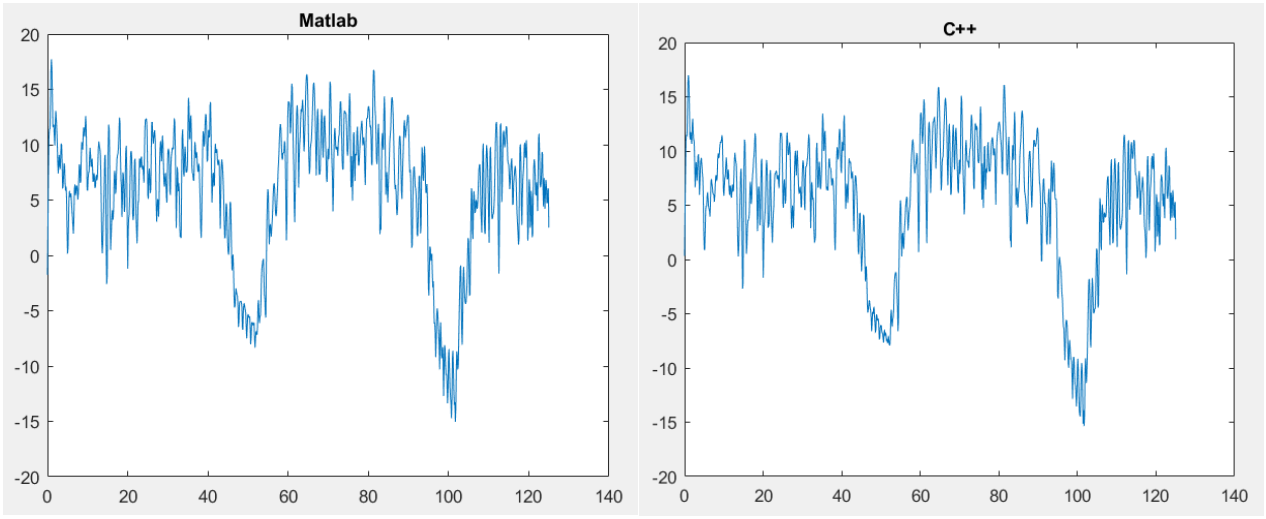
```
void   MBT_Fourier::forwardBluesteinFFT(std::vector<std::complex<float>   >&   inputData,   const
MBT_FourierOptions option)
{
    MBT_FourierBluestein::bluestein(inputData, getExponentSign(option));
    //forwardScaling(inputData, option); //No done in fft of
http://stackoverflow.com/questions/10121574/safe-and-fast-fft

}

template<typename T>
void MBT_Fourier::radix2Reorder(std::vector<T>& inputData)
{
    int j = 0;
    for (int i = 0; i < inputData.size() - 1; i++)
    {
        //Swap values
        if (i < j)
        {
            T temp = inputData[i];
            inputData[i] = inputData[j];
            inputData[j] = temp;
        }

        //int len = (int)inputData.size();
```

```
        int len = (int)inputData.size()/2; // like in
http://stackoverflow.com/questions/10121574/safe-and-fast-fft


        //do // Comment by Fanny Grosselin on 2017/01/20
        //{ // Comment by Fanny Grosselin on 2017/01/20
            //len >>= 1; // Comment by Fanny Grosselin on 2017/01/20
            j ^= len;
        //} // Comment by Fanny Grosselin on 2017/01/20
        while ((j & len) == 0)
        {// add these lines like in http://stackoverflow.com/questions/10121574/safe-and-fast-
fft

            len/=2;
            j^=len;
        };
    }
}


void    MBT_Fourier::radix2Step(std::vector<std::complex<float>    >&    inputData,    const    int
exponentSign, const int levelSize, const int indexInLevel)
{
    // Twiddle Factor
    const float  PI_F=3.14159265358979f;
    float exponent = (exponentSign * indexInLevel) * PI_F / levelSize;
    std::complex<float> w (cos(exponent), sin(exponent));

    //int step = levelSize << 1; // Commented by Fanny Grosselin 2017/01/20
    //for (int i = indexInLevel; i < inputData.size(); i += step)
    for (int i = indexInLevel; i < inputData.size(); i += 2*levelSize) // like on
http://stackoverflow.com/questions/10121574/safe-and-fast-fft

    {
        std::complex<float> value = inputData[i];
        std::complex<float> modifier = w * inputData[i + levelSize];
        inputData[i] = value + modifier;
        inputData[i + levelSize] = value - modifier;
    }
}
```

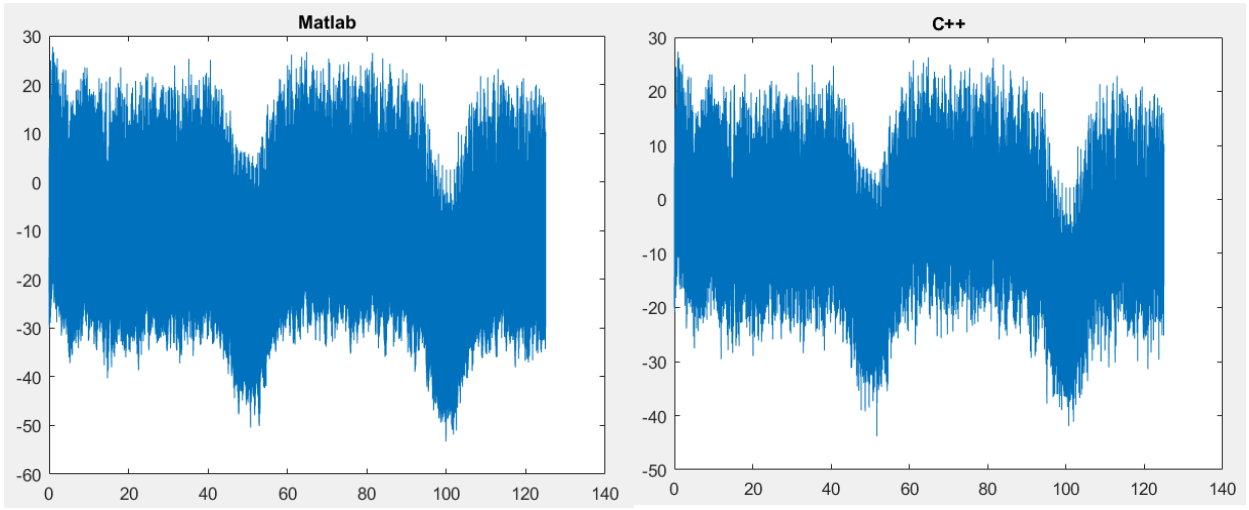
Signal of 250 datapoints:




Signal of 5000 datapoints:




Signal of 160000 datapoints:



## 5. *Adjustement of MBT_PWelchComputer to have the same result than with Matlab and remove some changes in MBT_Fourier*

.

[psdM,fM] = pwelch(inputData, [],[],[],250)
VS
Eight change of MBT_PWelchComputer and Fourth change of MBT_Fourier

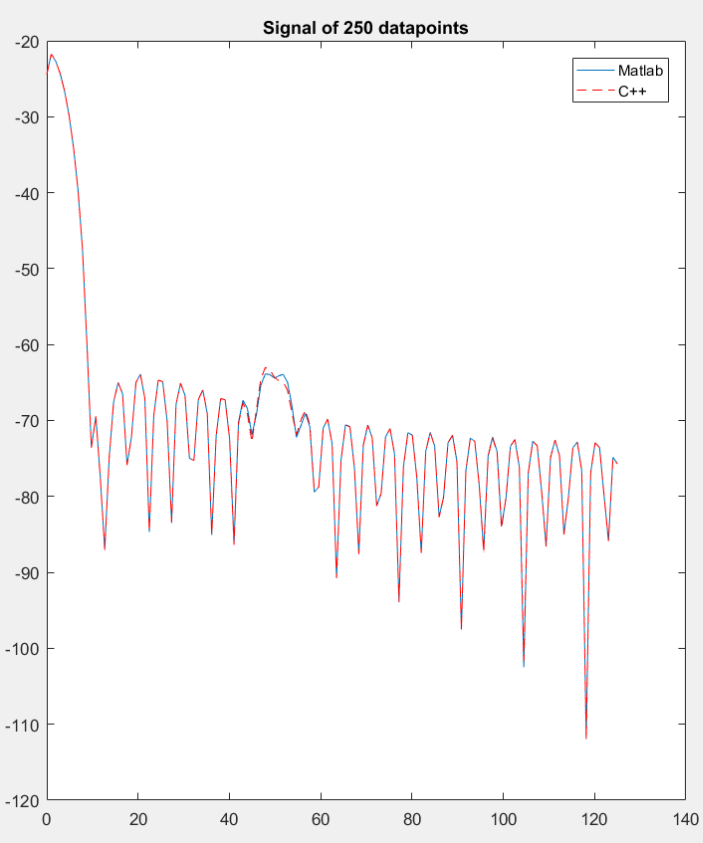
**Eight change of MBT_PWelchComputer.cpp:**

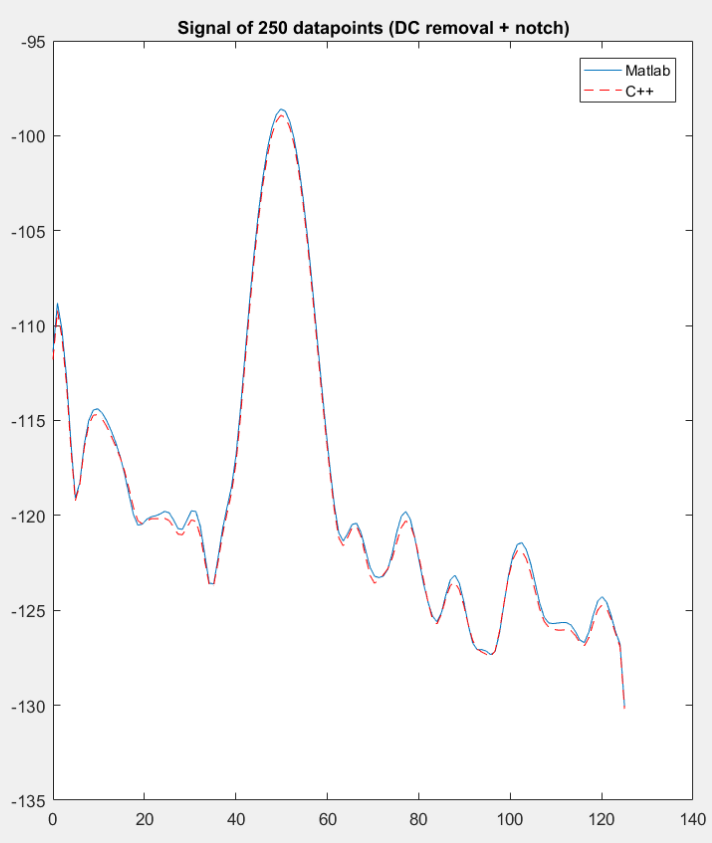
1) Rechange floor to ceil in the computation of powerOfTwoLength
2) In the one-sided spectrum, choose 1 point over 2 points because powerOfTwoLength is 2 times higher than what we want in Matlab.

**Fourth change of MBT_Fourier.cpp:**

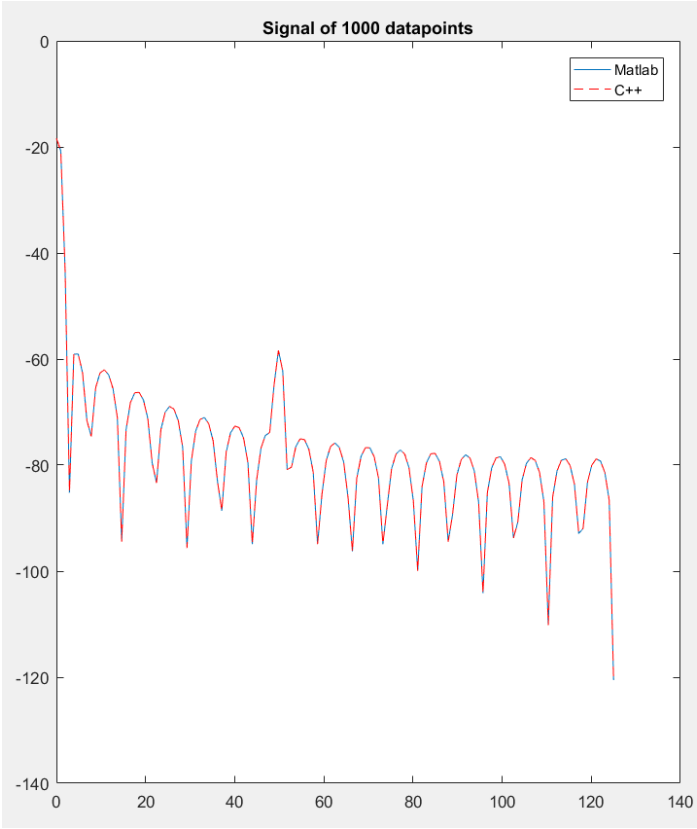
1) Rechange floor to ceil in the computation of powerOfTwoLength
2) Redo padding with the mirror of the signal instead of zero-padding (in the member functions that are not used for the computation of the spectrum.

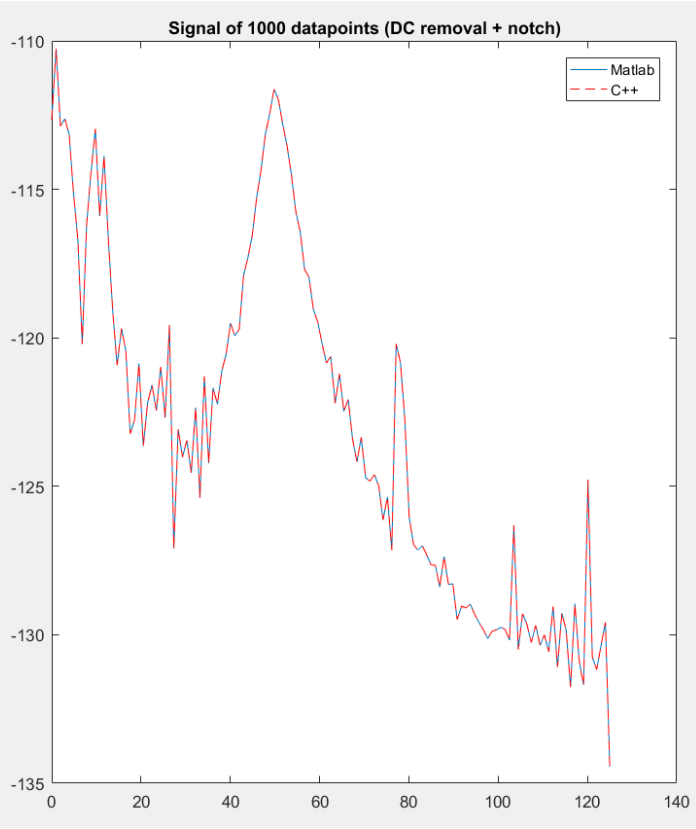
Signal of 250 datapoints (1s): spectrum are almost equal in both cases



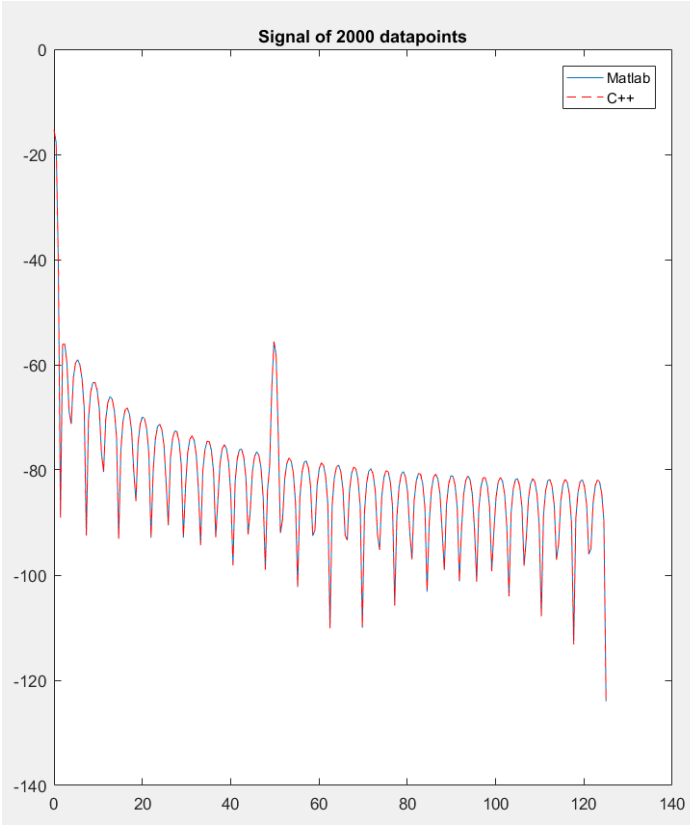



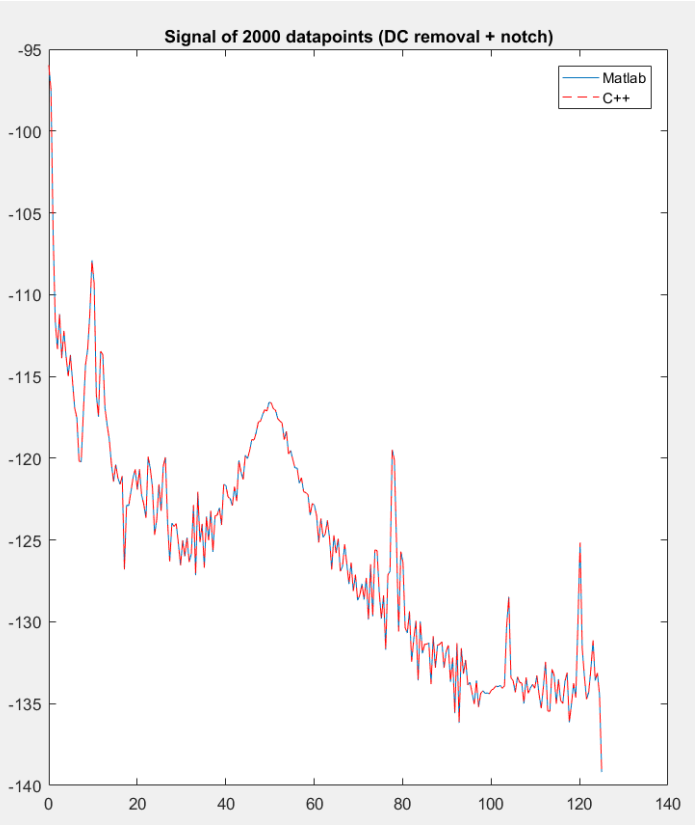
Signal of 1000 datapoints (4s): spectrum are equal in both cases



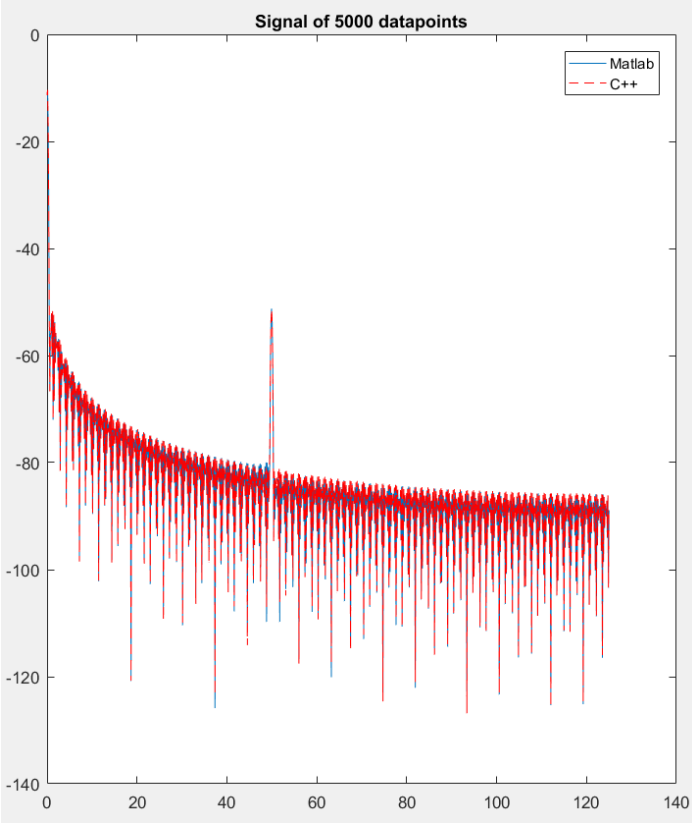



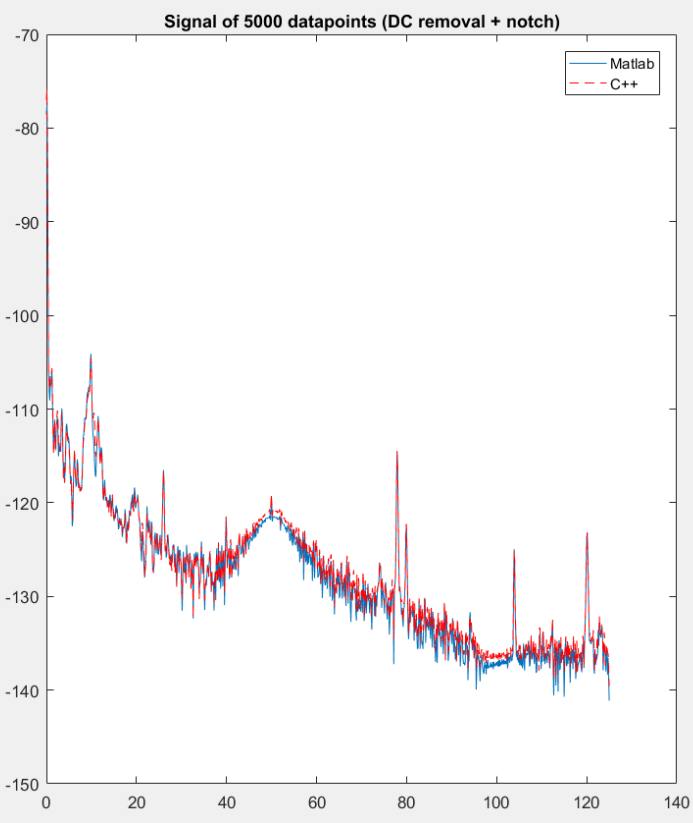

Signal of 2000 datapoints (8s): spectrum are equal in both cases



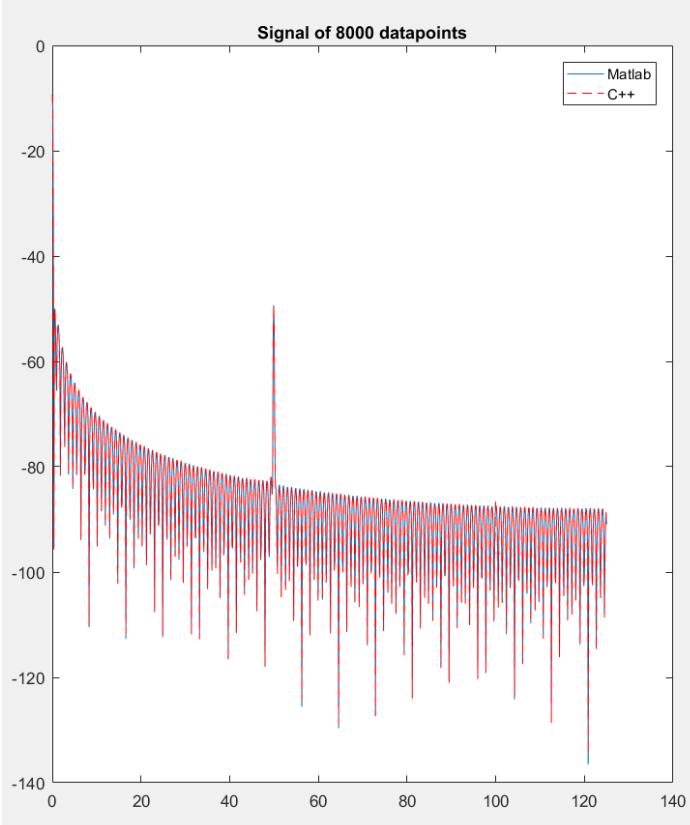



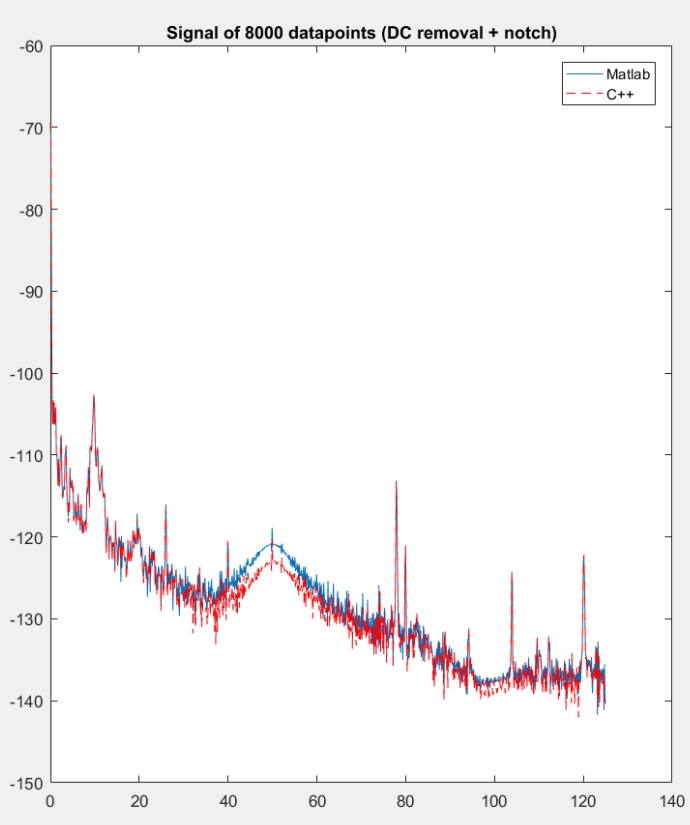
Signal of 5000 datapoints (20s): spectrum are equal in 1st case and almost equal in 2nd case




Signal of 8000 datapoints (32s): spectrum are equal in 1st case and almost equal in 2nd case



Signal of 30000 datapoints: (around 8s to compute spectrum) spectrum are equal in both cases