Non-Parametric Spectral Estimation methods

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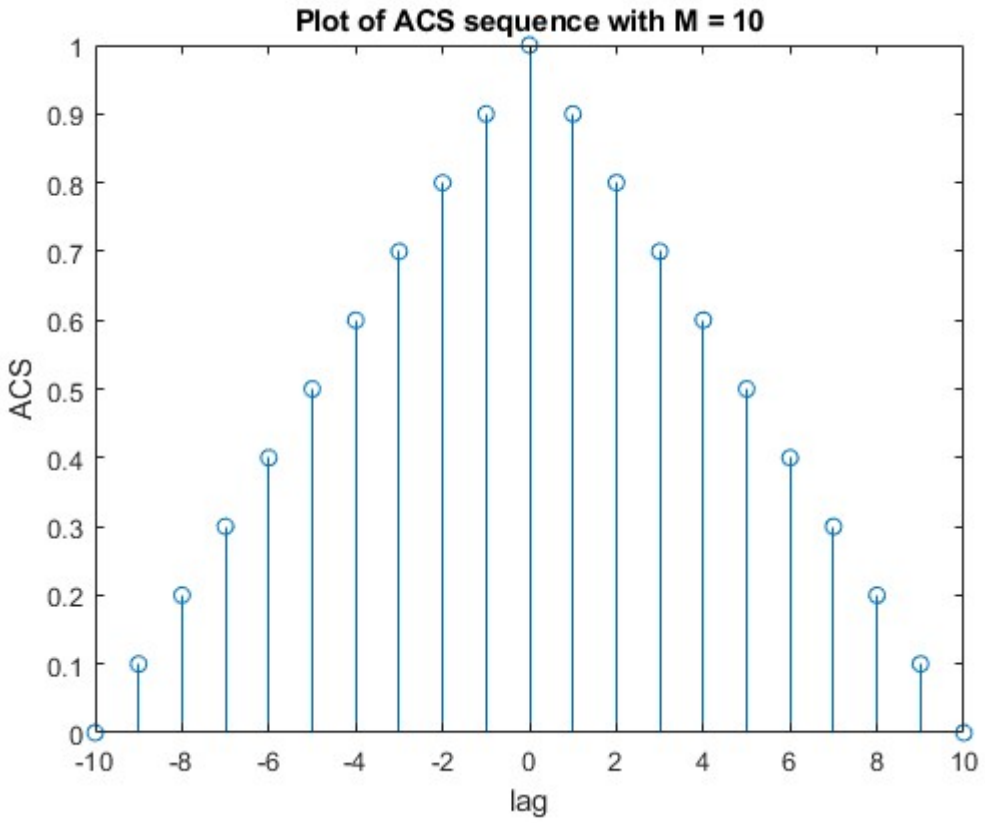
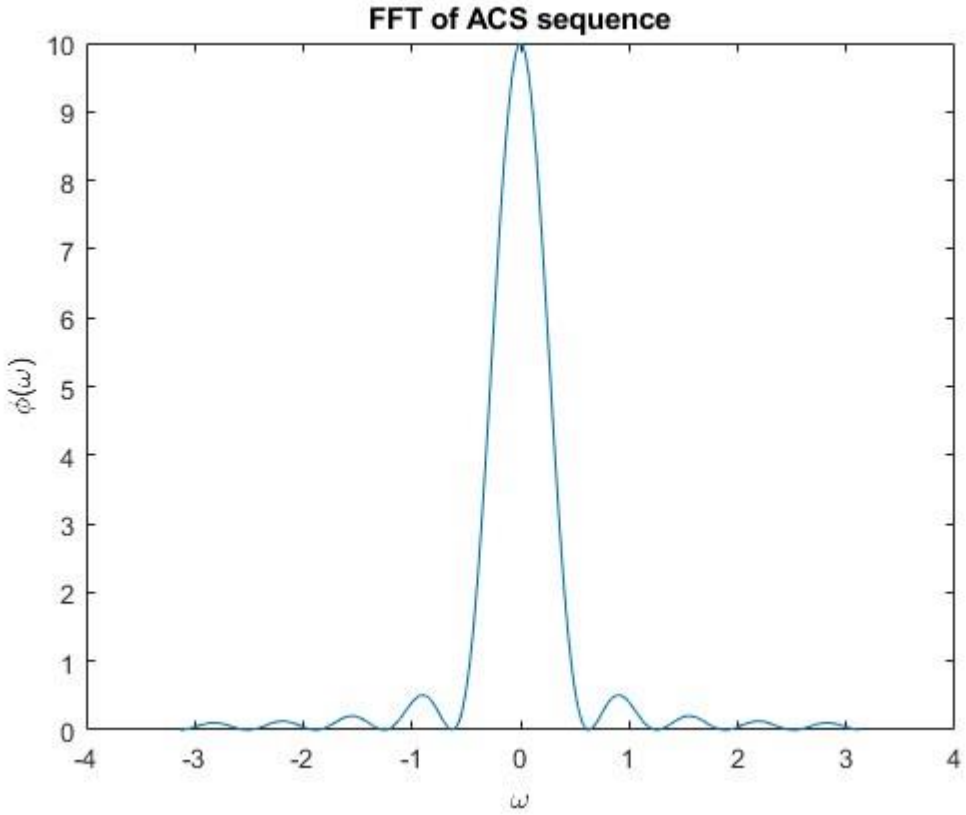
Question 1



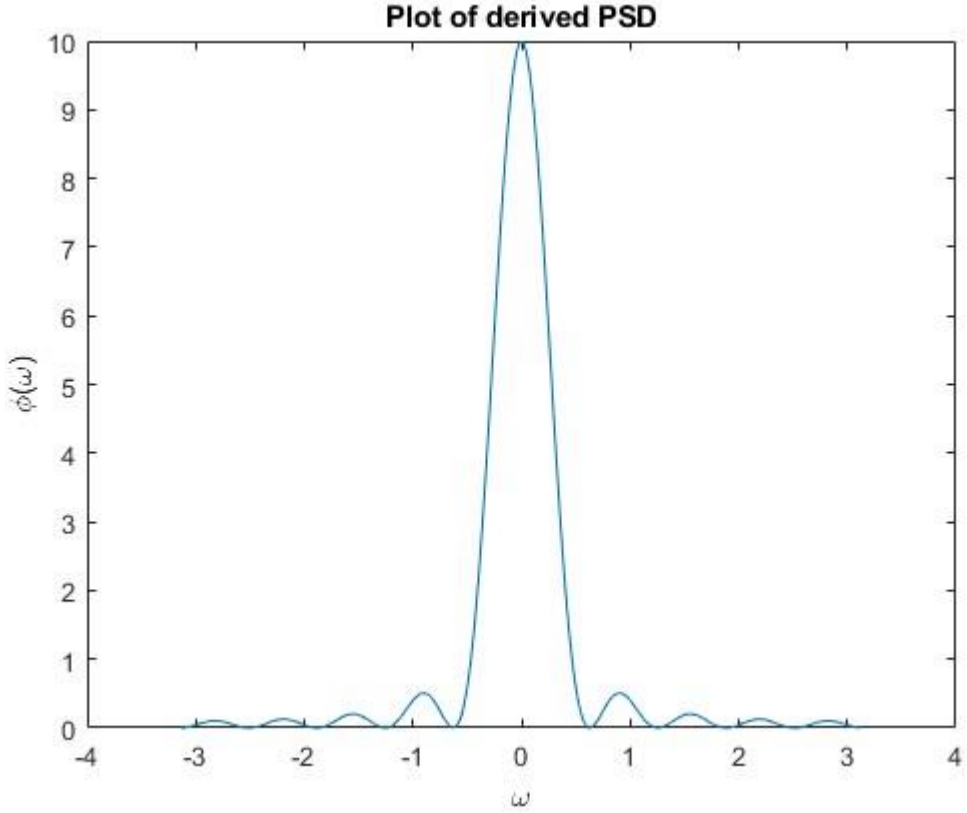
‘nnz(xf<0)’ shows that all the elements of xf are non-negative.

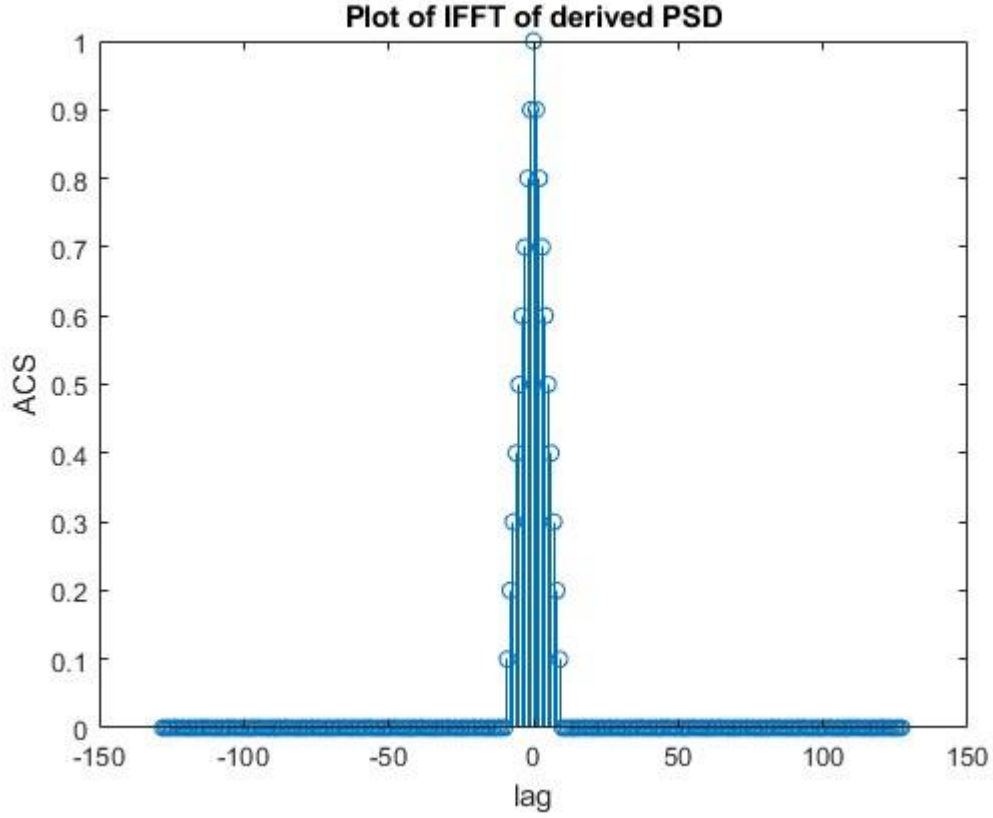
Zero padding the input sequence before applying DTFT giving more samples in DFT which in turn provides a better spectral representation of the signal. FFT of a circular shifted signal gives gives the spectral content multiplied by exponential whose effect gets nullified while calculating PSD because of mod operator.

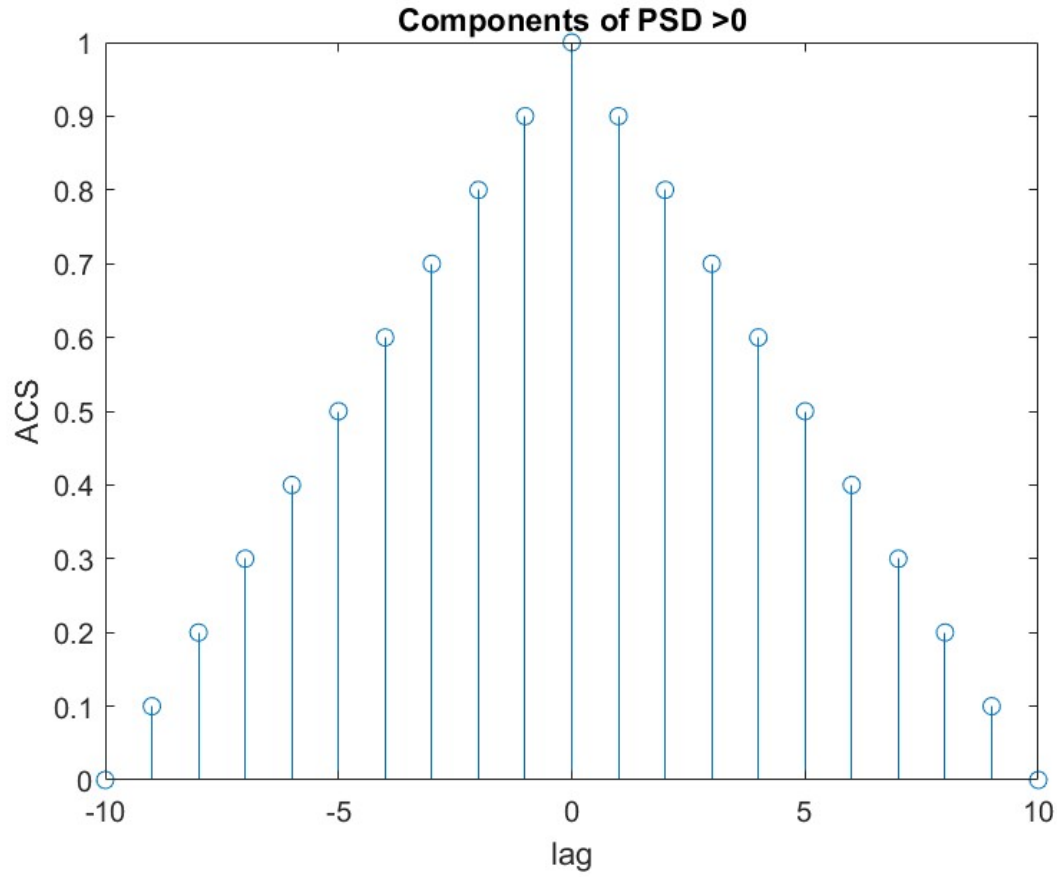


Derived PSD

```
yf=(sin(M*w/2).^2)./(M*sin(w/2).^2);
```

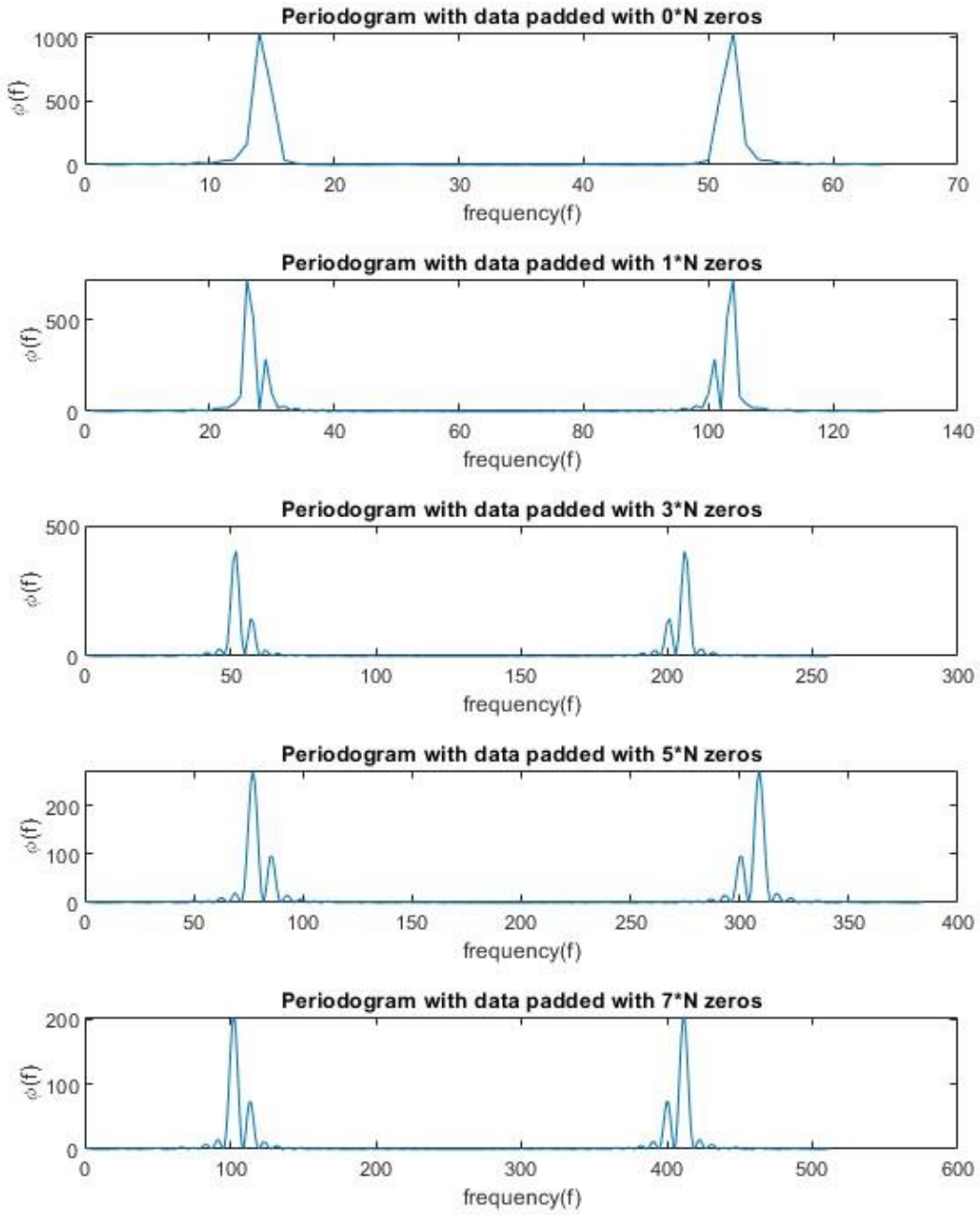

Plot of derived PSD
10
9
8
7
6
5
4
3
2
1
0
$\phi(\omega)$
-4
-3
-2
-1
0
1
2
3
4
ω


Plot of IFFT of derived PSD
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ACS
-150
-100
-50
0
50
100
150
lag



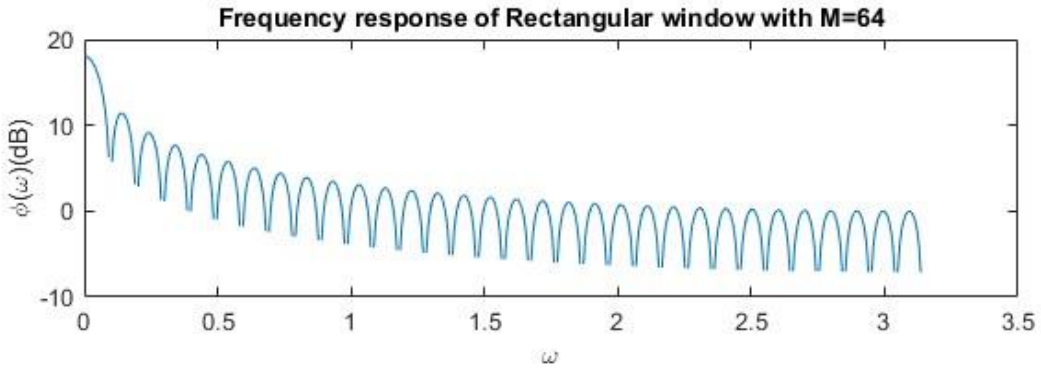
The above plot shows that y closely approximates ACS.

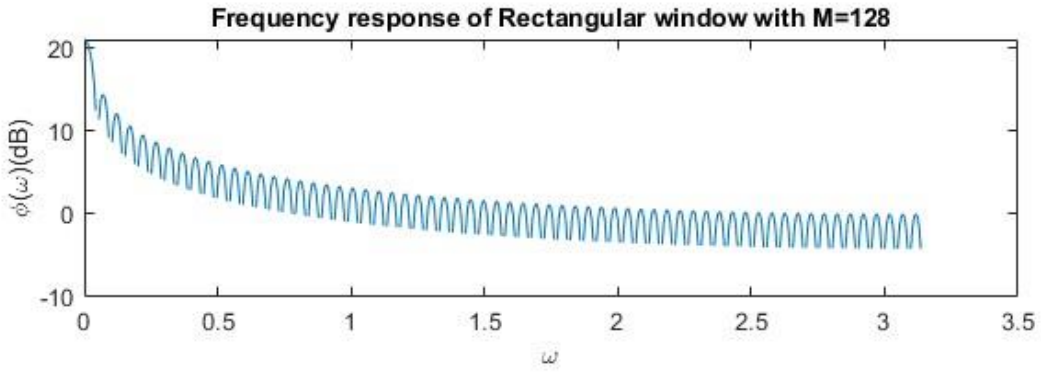
Question 2:

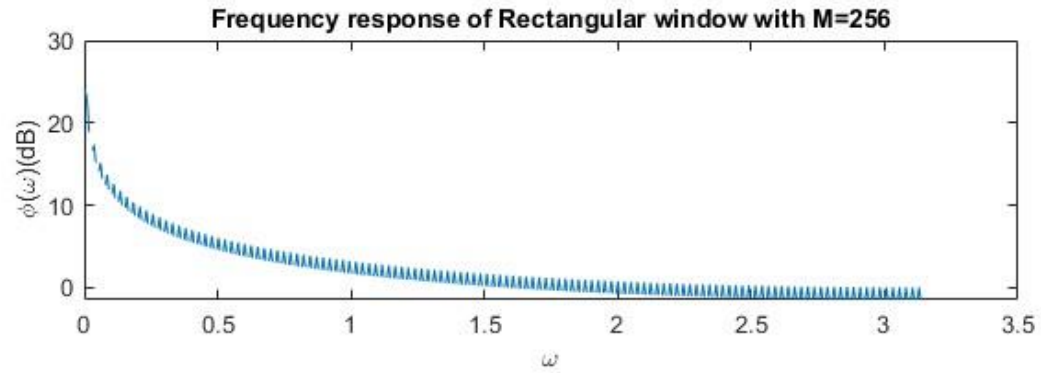


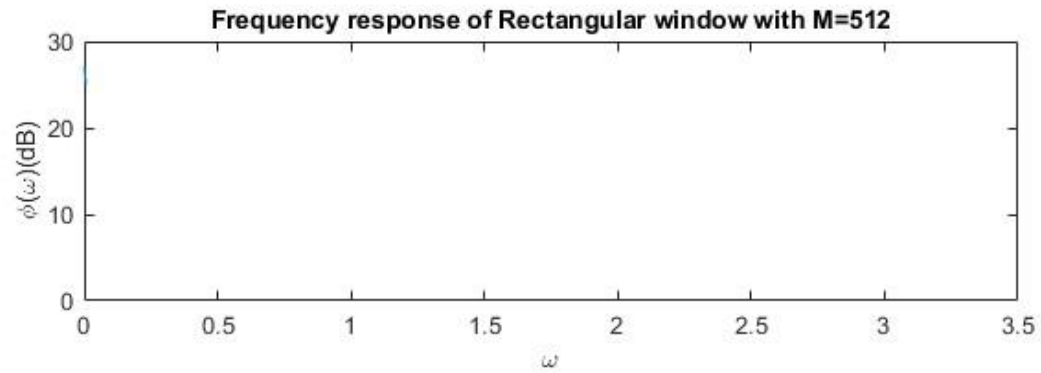
Zero padding a sequence before FFT gives a better sampling upon the DTFT which gives us a better understanding of the spectral content, even though there is no additional spectral content. Due to this the first periodogram doesn't give a good spectral content of the signal.

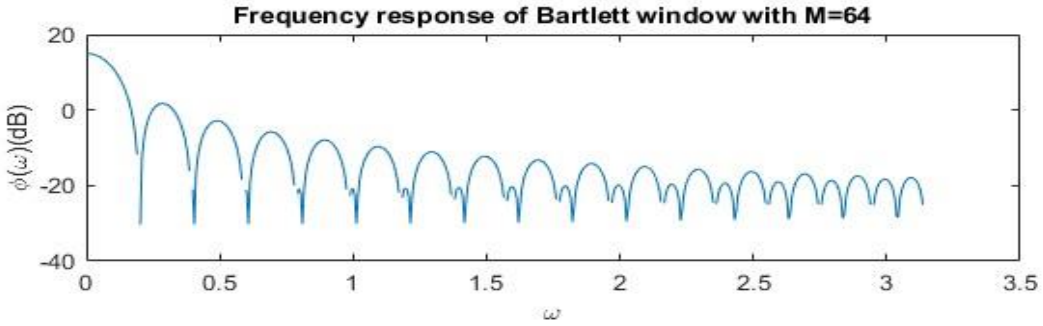
Question3:

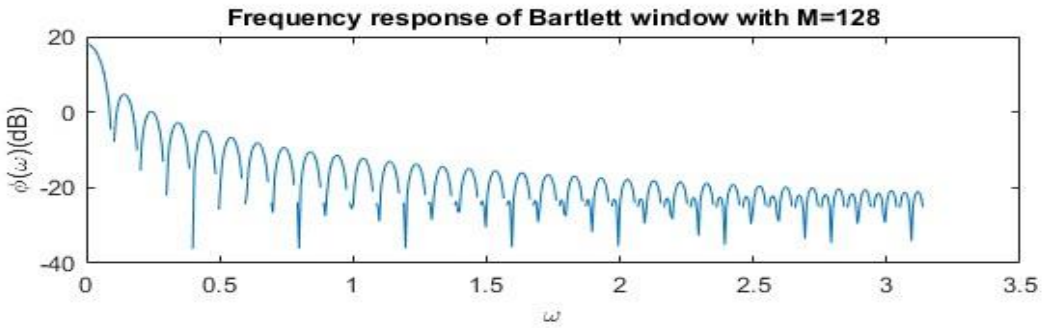

Frequency response of Rectangular window with M=64
20
10
0
-10
$\phi(\omega)$(dB)
0
0.5
1
1.5
2
2.5
3
3.5
ω

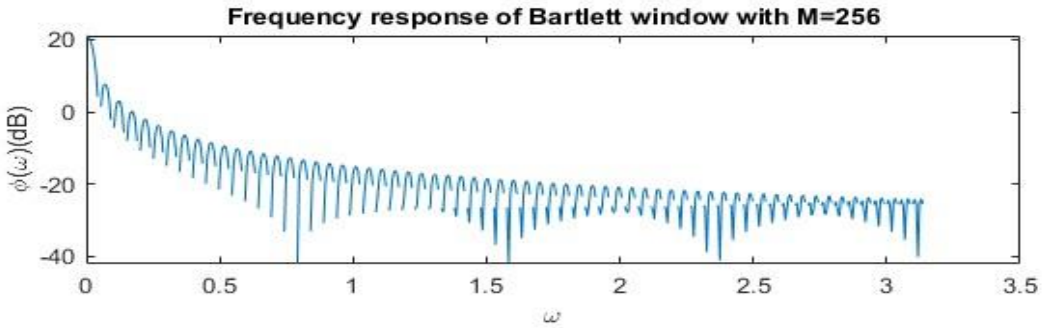

Frequency response of Rectangular window with M=128
20
10
0
-10
$\phi(\omega)$(dB)
0
0.5
1
1.5
2
2.5
3
3.5
ω

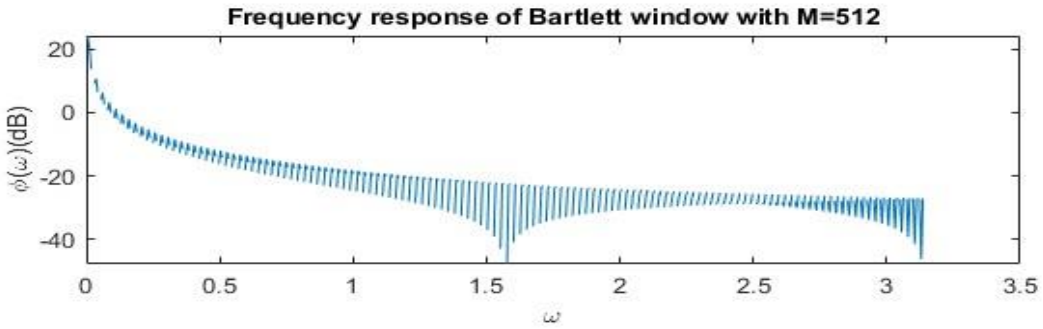

Frequency response of Rectangular window with M=256
30
20
10
0
$\phi(\omega)$(dB)
0
0.5
1
1.5
2
2.5
3
3.5
ω


Frequency response of Rectangular window with M=512
30
20
10
0
$\phi(\omega)$(dB)
0
0.5
1
1.5
2
2.5
3
3.5
ω



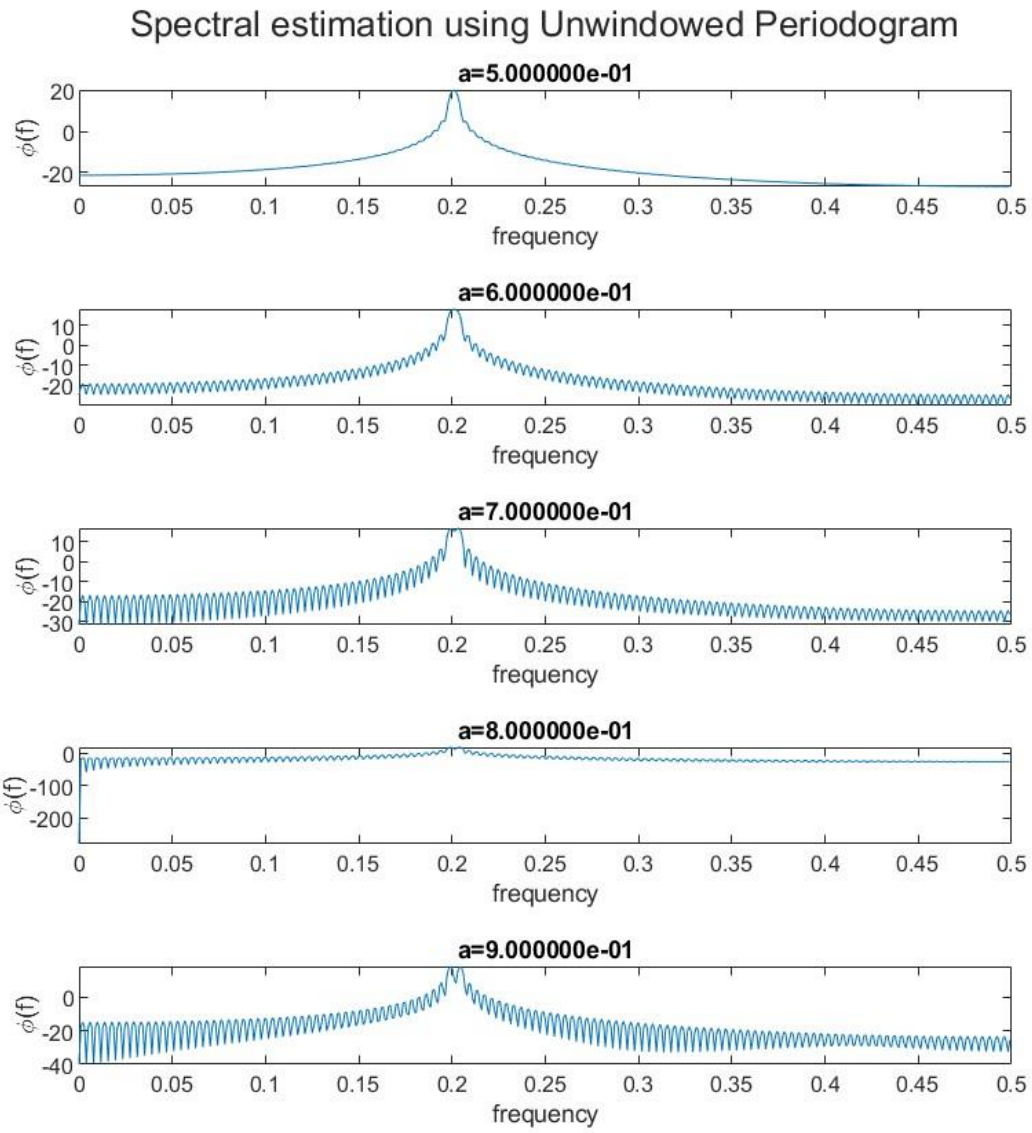


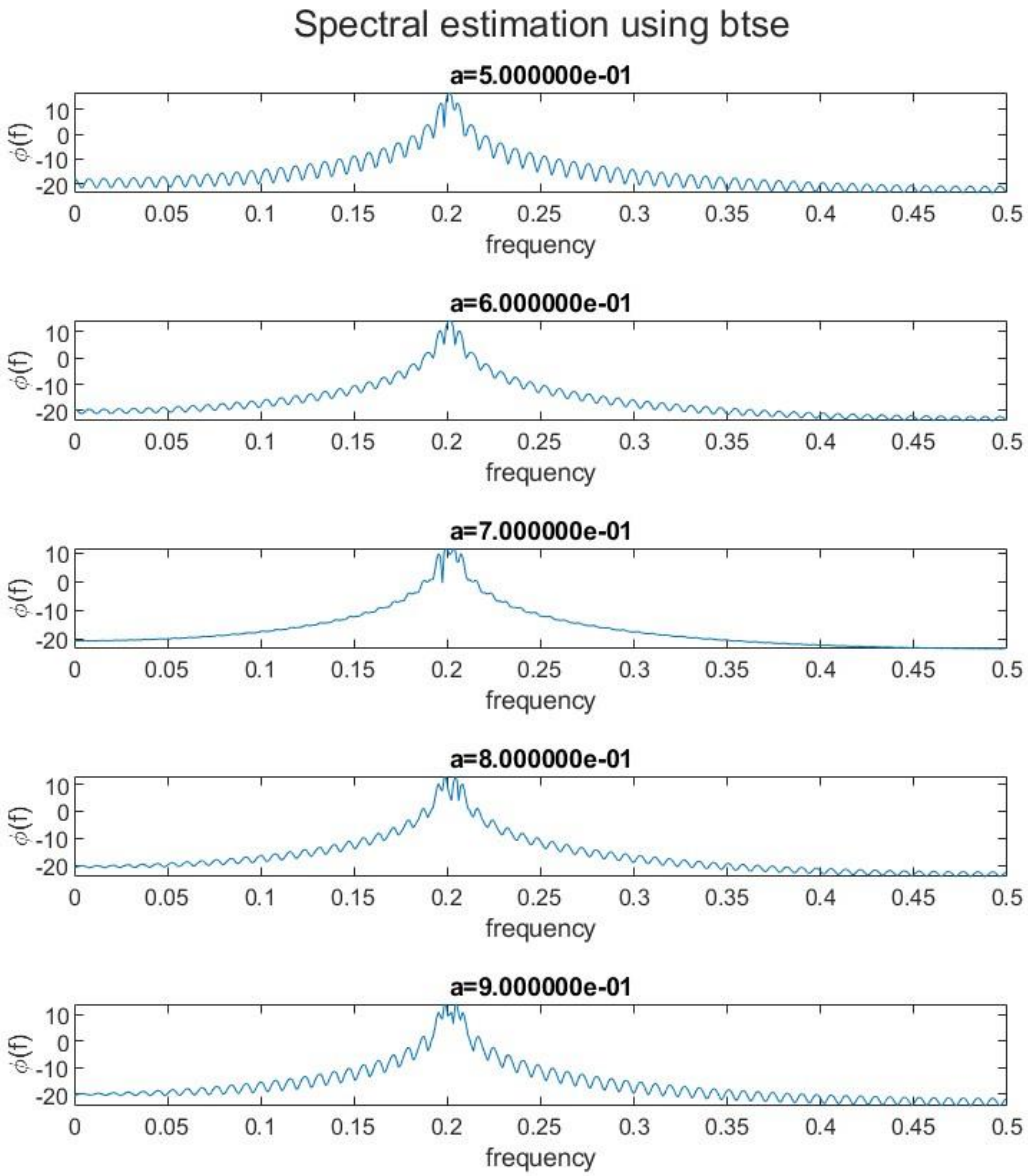




For rectangular window the 3dB bandwidth is at 30.44, 15.2,7.6,3.8 pi*micro radians per sample.

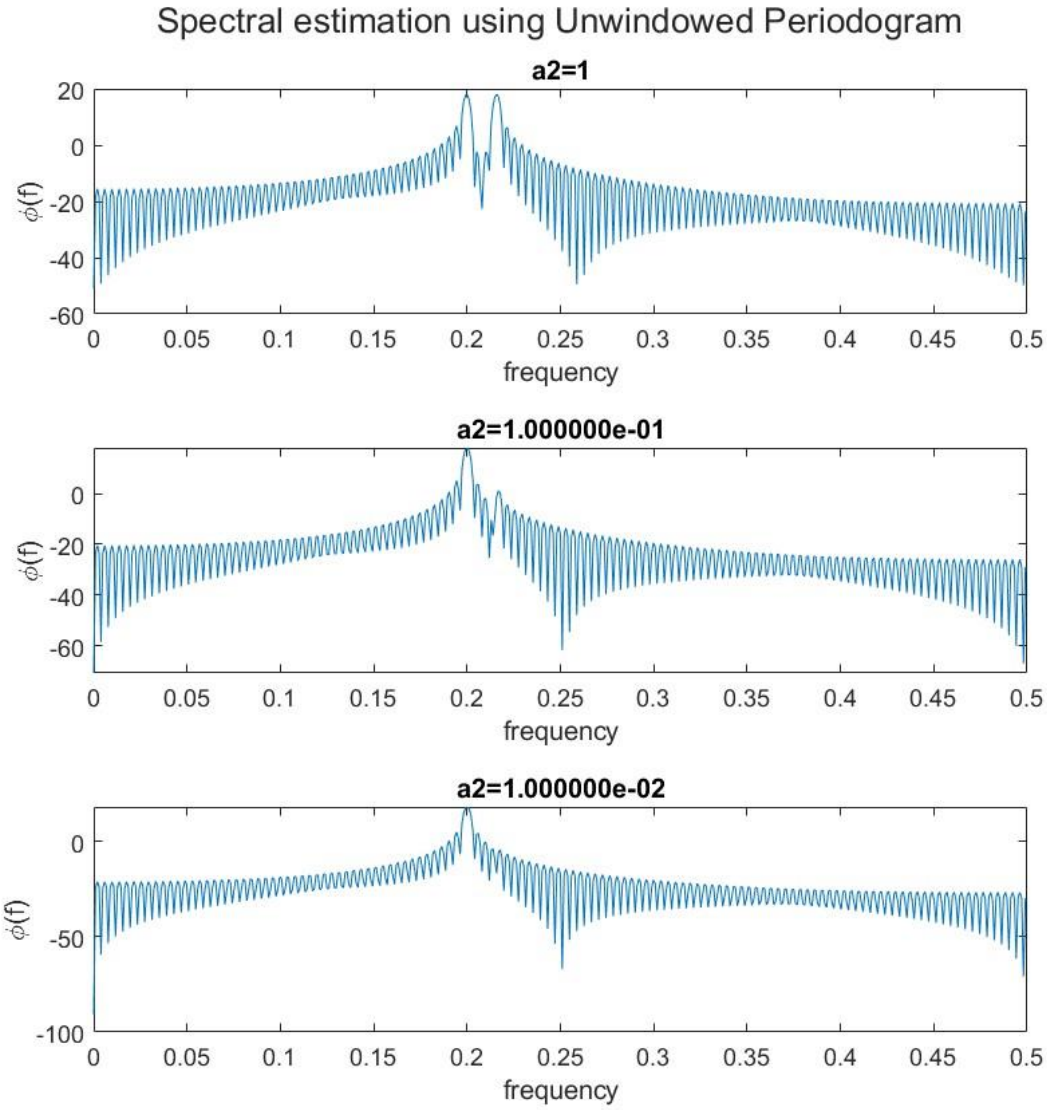
For Bartlett window the 3dB bandwidth is at 12.4,6.1,3,1.5 pi*milli radians per sample.

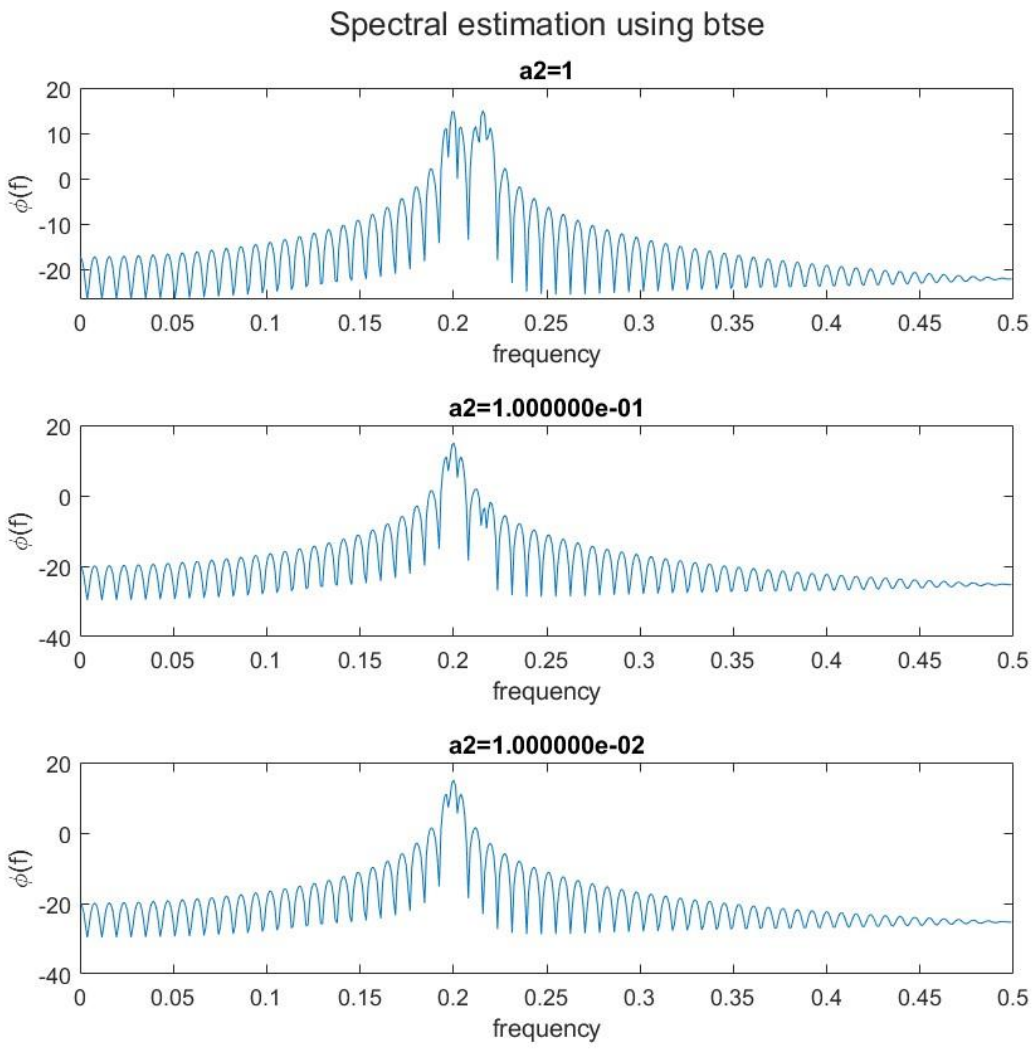

Spectral estimation using Unwindowed Periodogram
a=5.000000e-01
a=6.000000e-01
a=7.000000e-01
a=8.000000e-01
a=9.000000e-01
ϕ(f)
frequency



For unwindowed periodogram the difference between two frequencies becomes prominent at alpha=0.9 whereas for Blackman-Tukey estimate with Bartlett window it becomes prominent at alpha=0.8. Additionally, it can be seen that the peaks are around 0.2 as given by us.

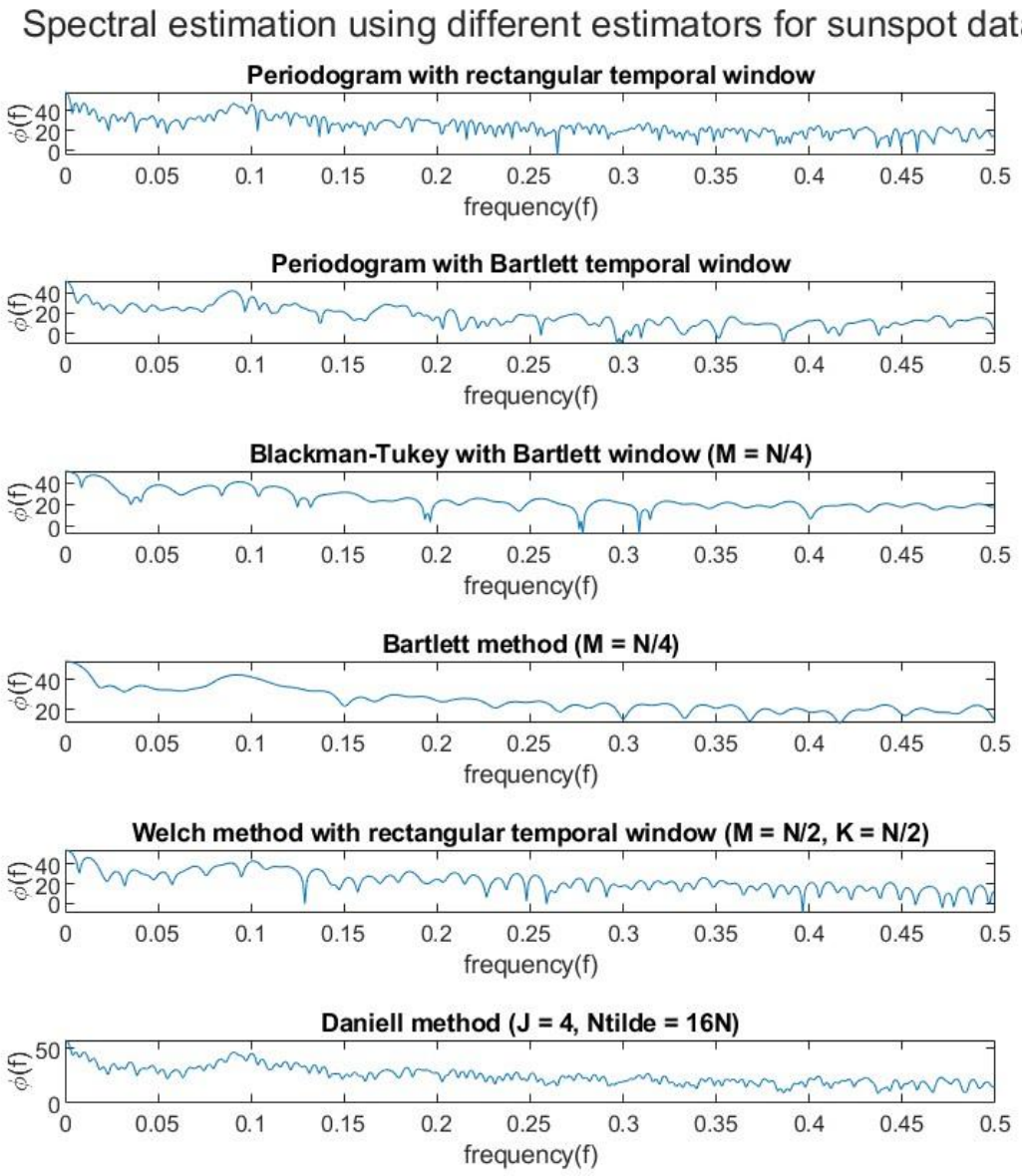
NOTE: Please zoom into the plots for better understanding.

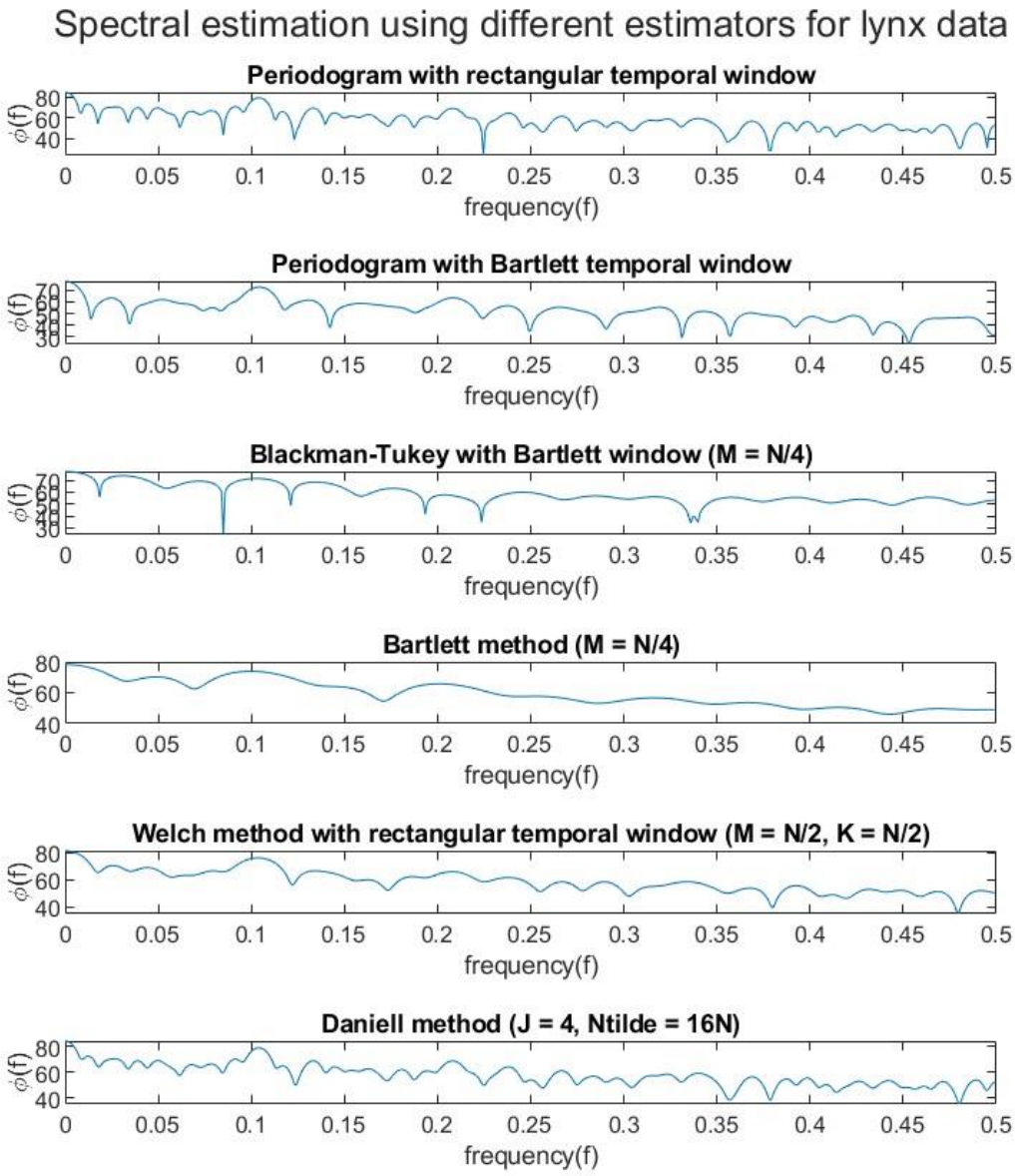

Spectral estimation using Unwindowed Periodogram
a2=1
20
0
-20
-40
-60
ϕ(f)
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
frequency
a2=1.000000e-01
0
-20
-40
-60
ϕ(f)
frequency
a2=1.000000e-02
0
-50
-100
ϕ(f)
frequency



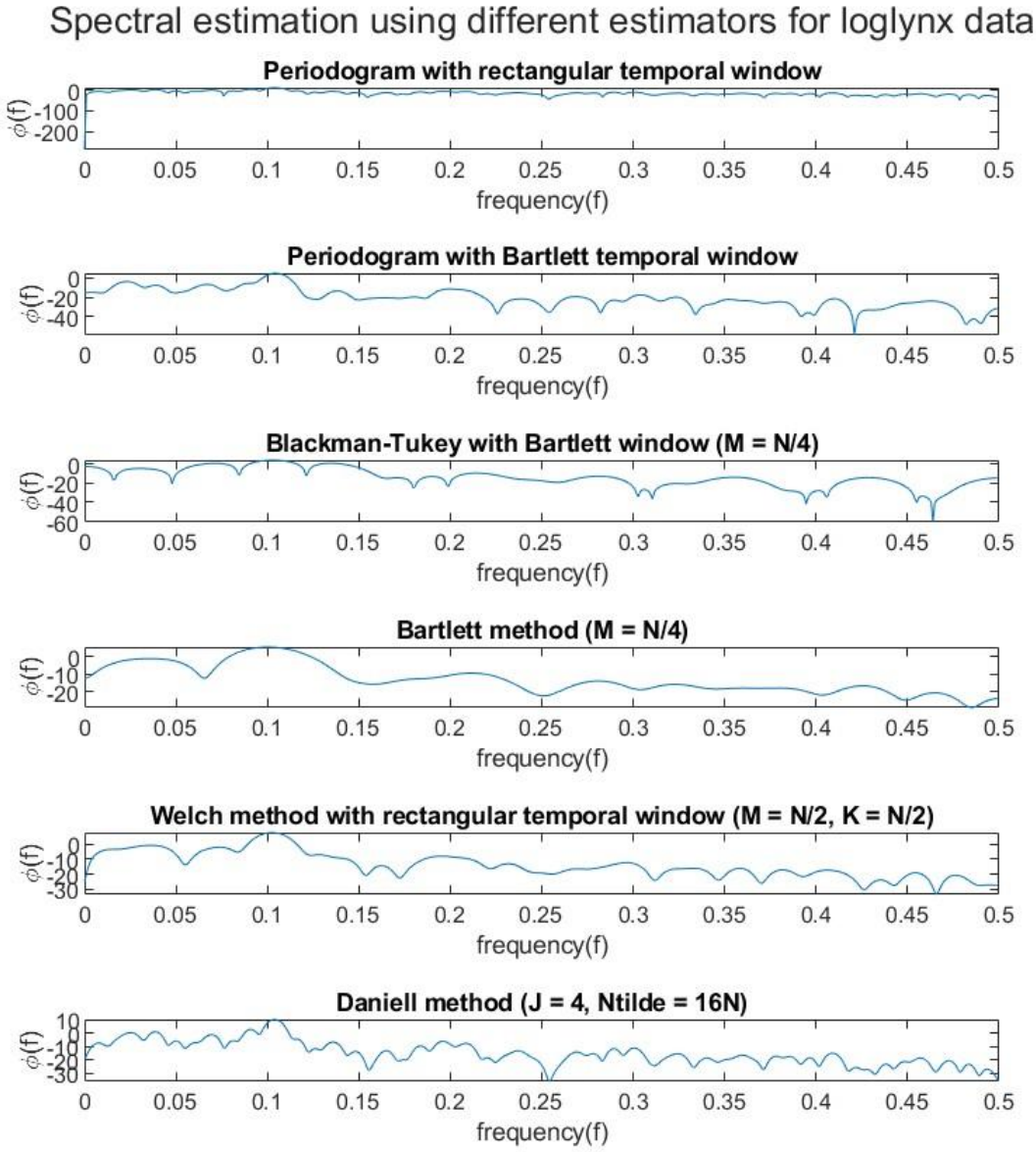
For unwindowed periodogram the difference between two components is visible at a2=1 where as Blackman-Tukey estimate with Bartlett window can identify at a2=0.1 also. Qualitatively Blackman-Tukey estimate with Bartlett window is a better spectral estimator because it has the ability to apply locally based on the window size and has the property of decaying the window weight as we go to the end of local window.

Question4:


Spectral estimation using different estimators for sunspot data
Periodogram with rectangular temporal window
Periodogram with Bartlett temporal window
Blackman-Tukey with Bartlett window (M = N/4)
Bartlett method (M = N/4)
Welch method with rectangular temporal window (M = N/2, K = N/2)
Daniell method (J = 4, Ntilde = 16N)
frequency(f)



For lynx data there is sinusoidal structure at 0.1 and 0.2 frequencies. For sunspot data there is sinusoidal structure at 0.09 frequency. Both of them has sinusoidal structure at 0 frequency (DC).



After applying non-linear transformation in lynx data, only the frequency around 0.1 becomes prominent which can be seen in the above plots.