Digital Signal Processing, Lab 2

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Chapter 1

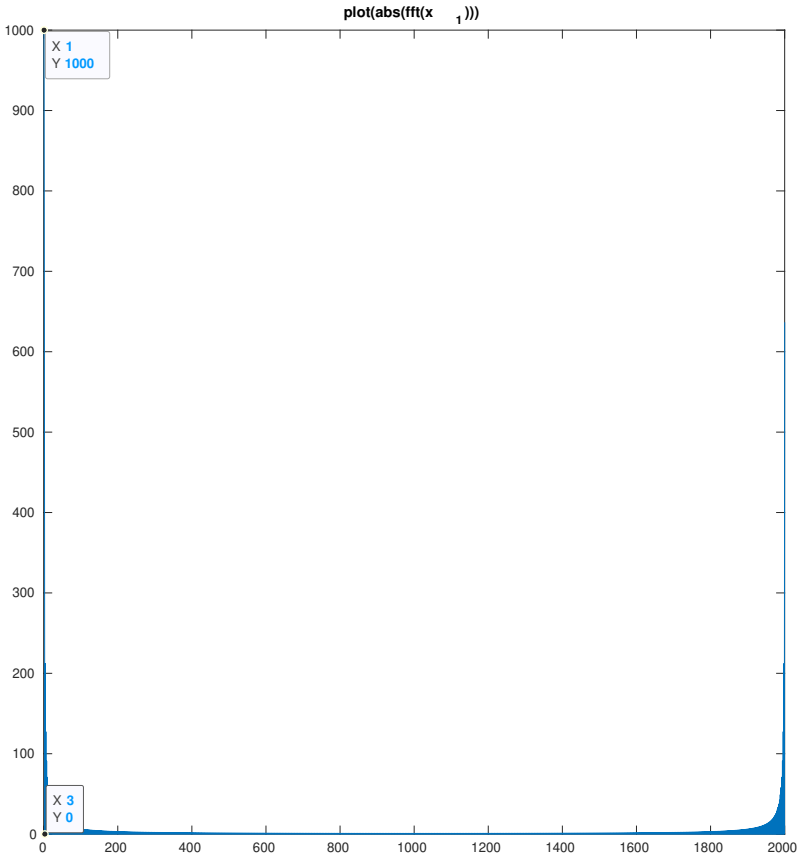
Task 1

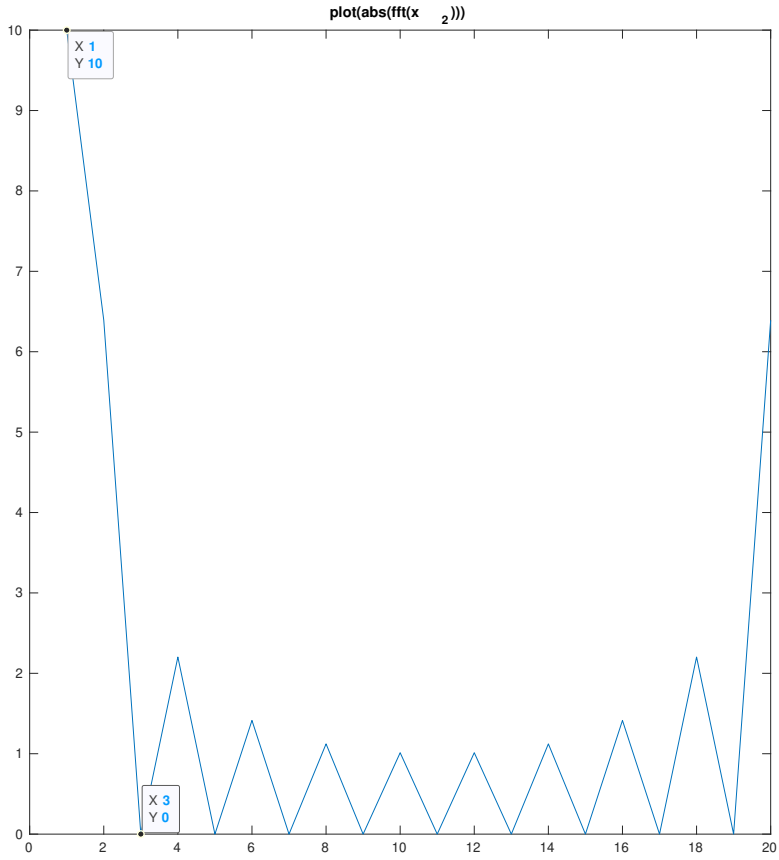
1.1 a)

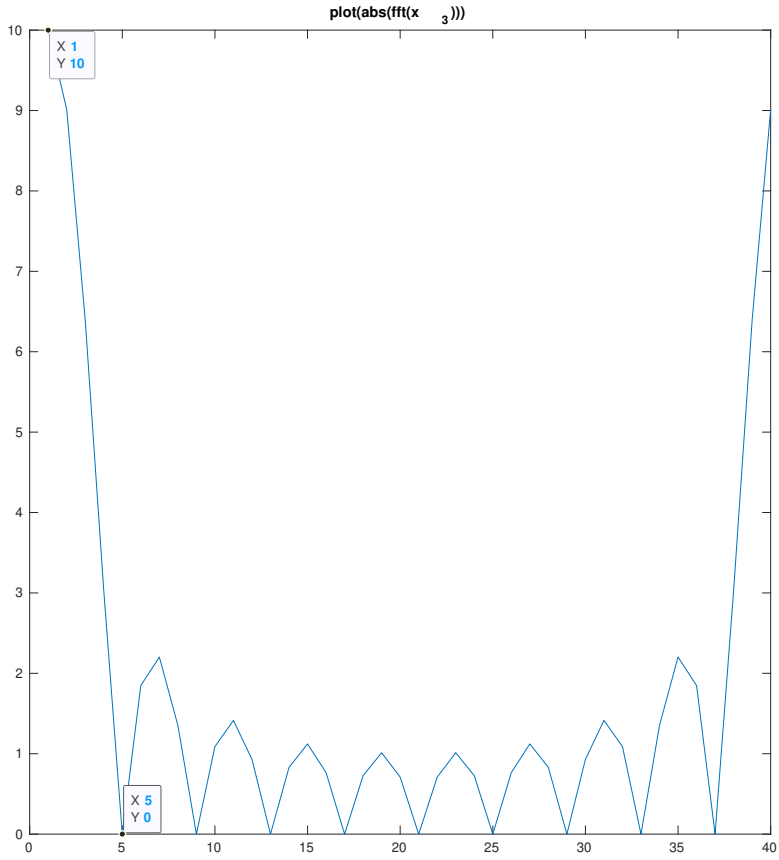
case	f_s	T	N	N_1	A_{max}	k_{null}	f_n at null	f at null
$x_1[n]$	1 MHz	2 ms	2000	1000	1000	2	0.001	1000
$x_2[n]$	10 kHz	2 ms	20	10	10	2	0.1	1000
$x_3[n]$	10 kHz	4 ms	40	10	10	4	0.1	1000

1.2 b, c, d, e, f, g

I used data tips from matlab to find maximum value in FFT and first zero value


plot(abs(fft(x 1)))
X 1
Y 1000
X 3
Y 0
1000
900
800
700
600
500
400
300
200
100
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000


plot(abs(fft(x 2)))
X 1
Y 10
X 3
Y 0
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
18
20


plot(abs(fft(x 3)))
X 1
Y 10
X 5
Y 0
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25
30
35
40

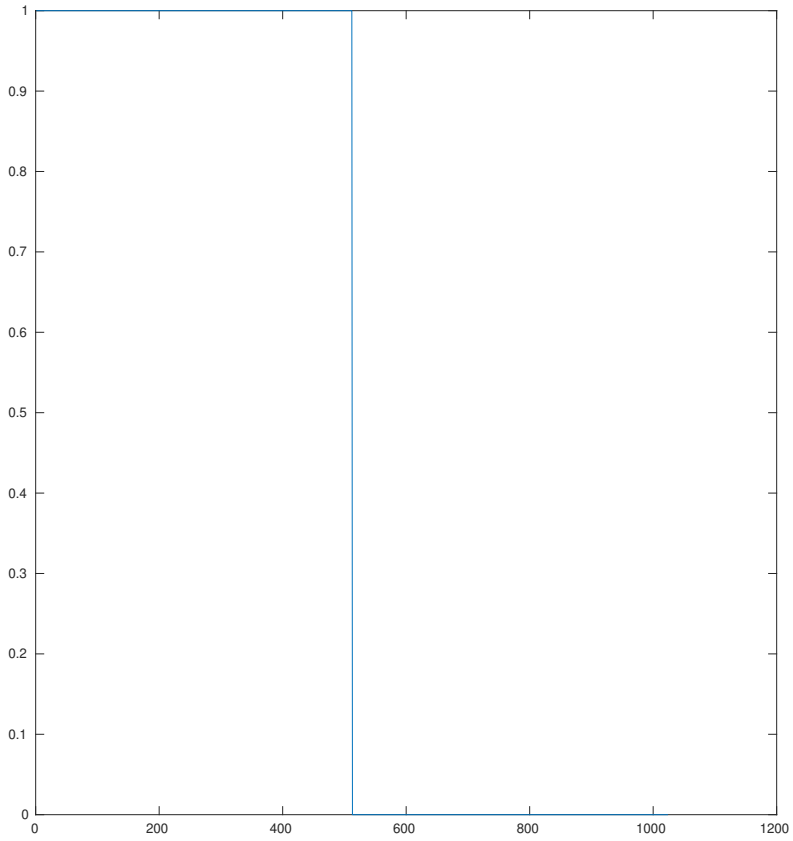
Chapter 2

Task 2

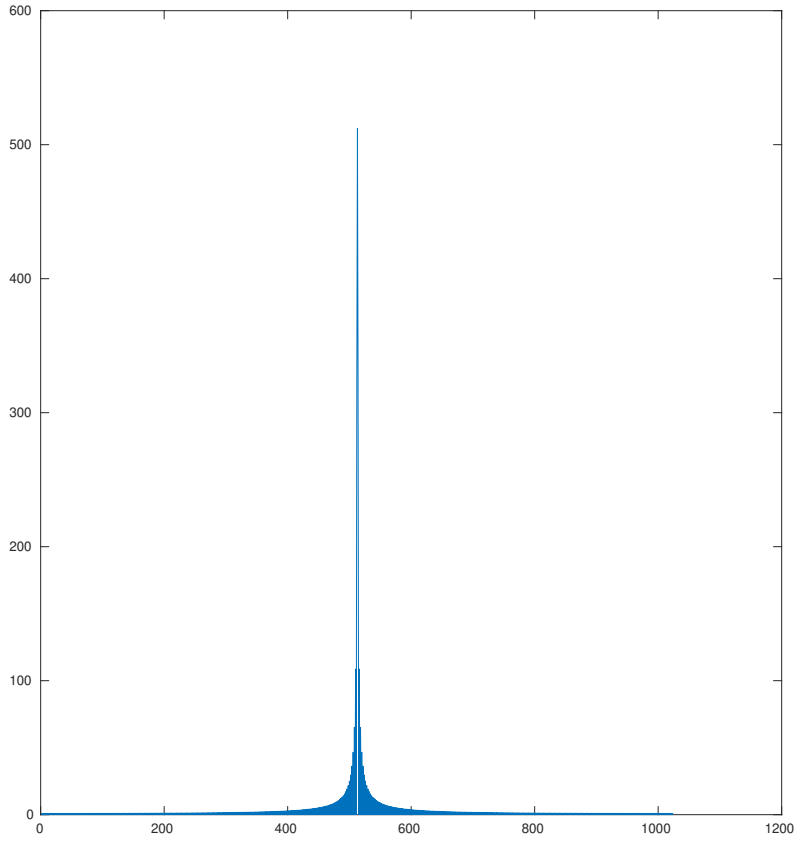
2.1 a

512 points square impulse

2.1.1 Signal plot



2.1.2 Magnitude FFT

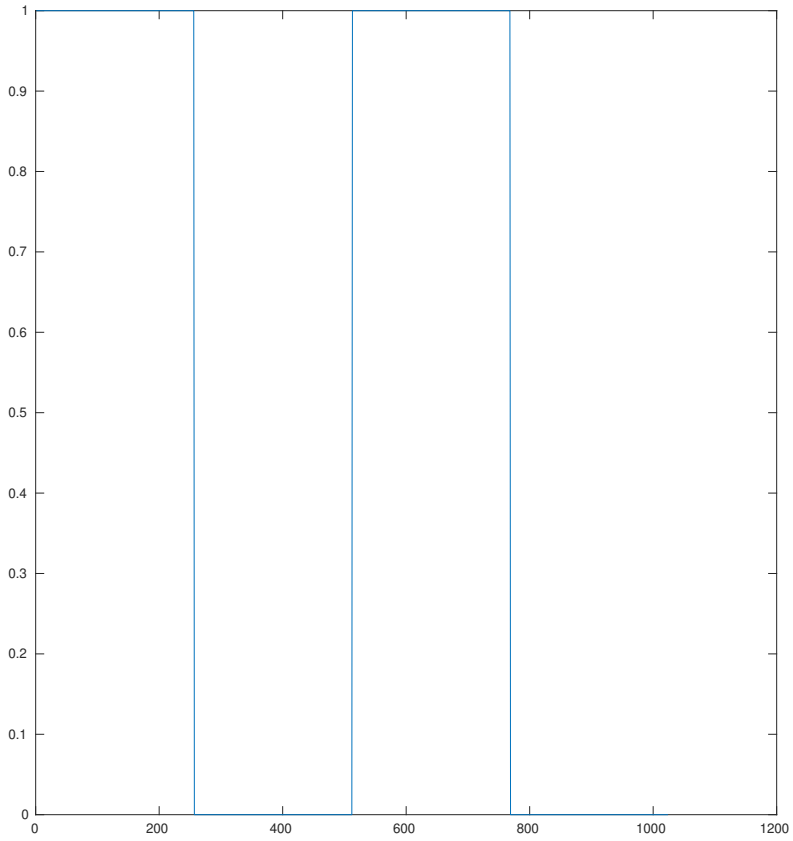


Number of zero crossings in FFT is equal to 511

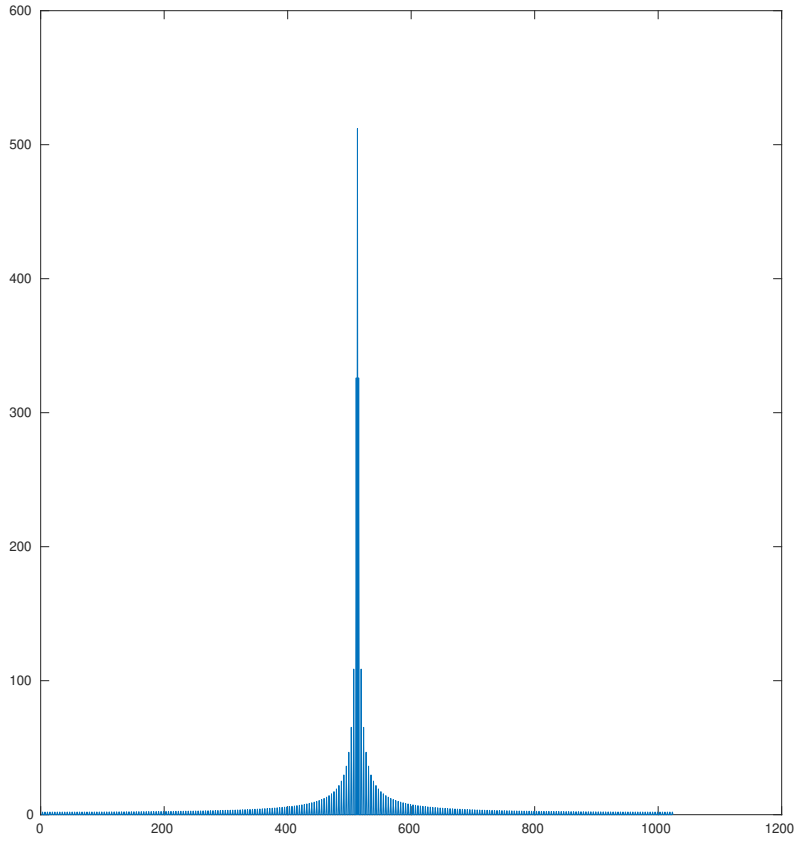
2.2 b

Narrower square impulses

2.2.1 Signal plot



2.2.2 Magnitude FFT

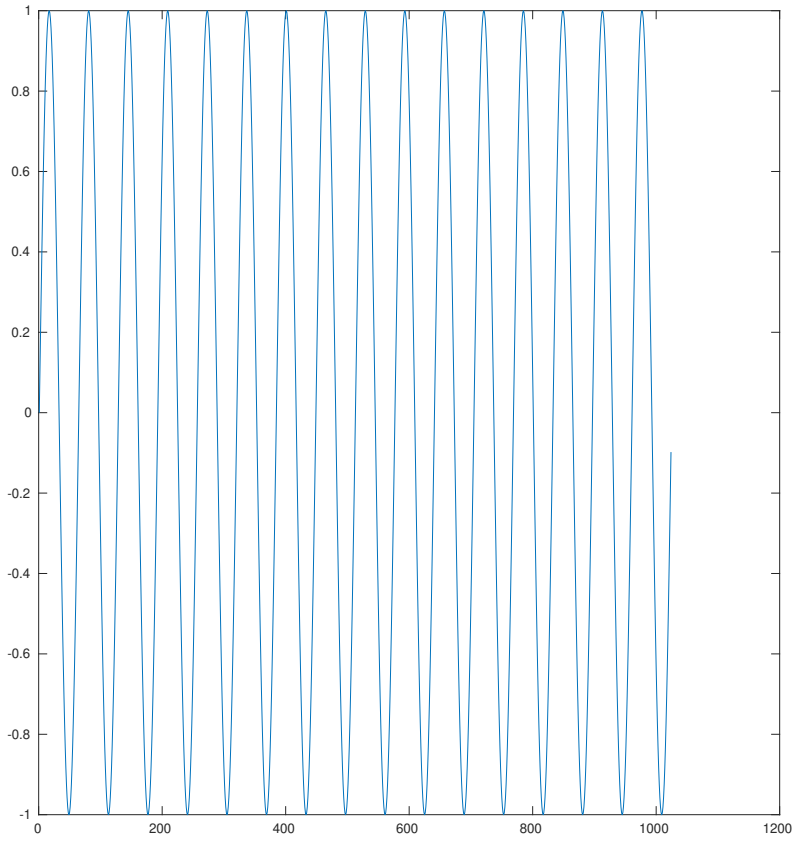


Number of zero crossings in FFT is equal to 767

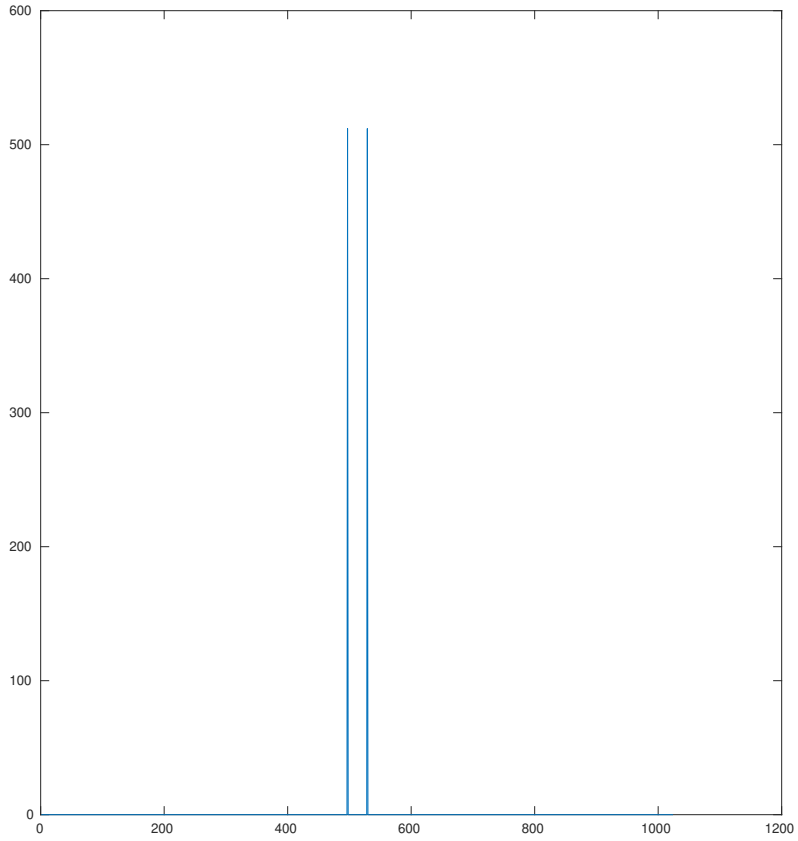
2.3 c

Sine wave with integer number of periods in window of 1024

2.3.1 Signal plot



2.3.2 Magnitude FFT

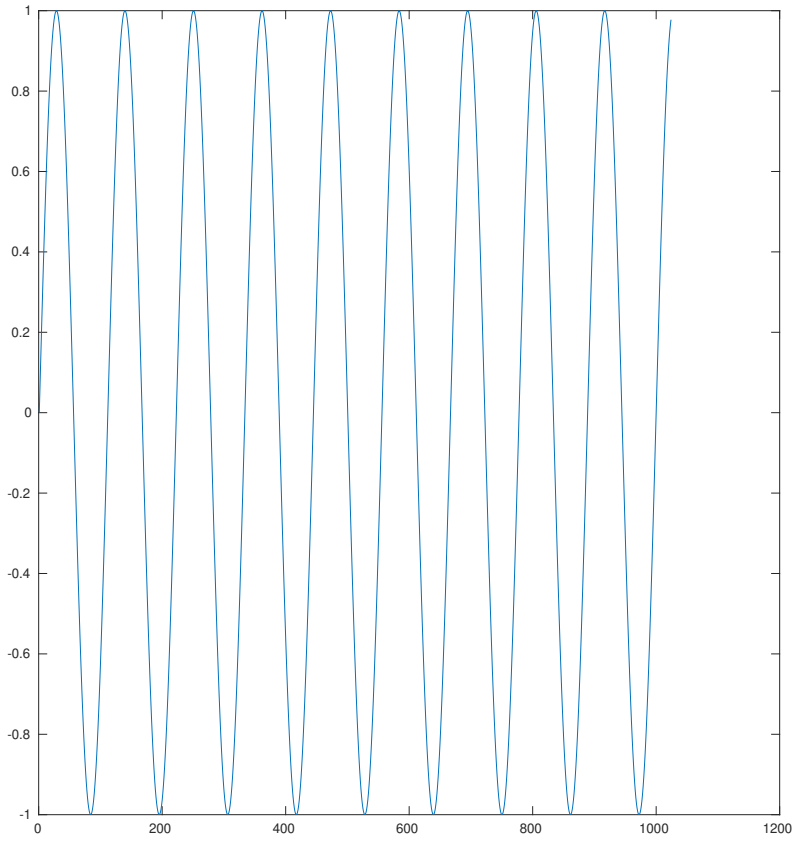


Location of the peak = 15

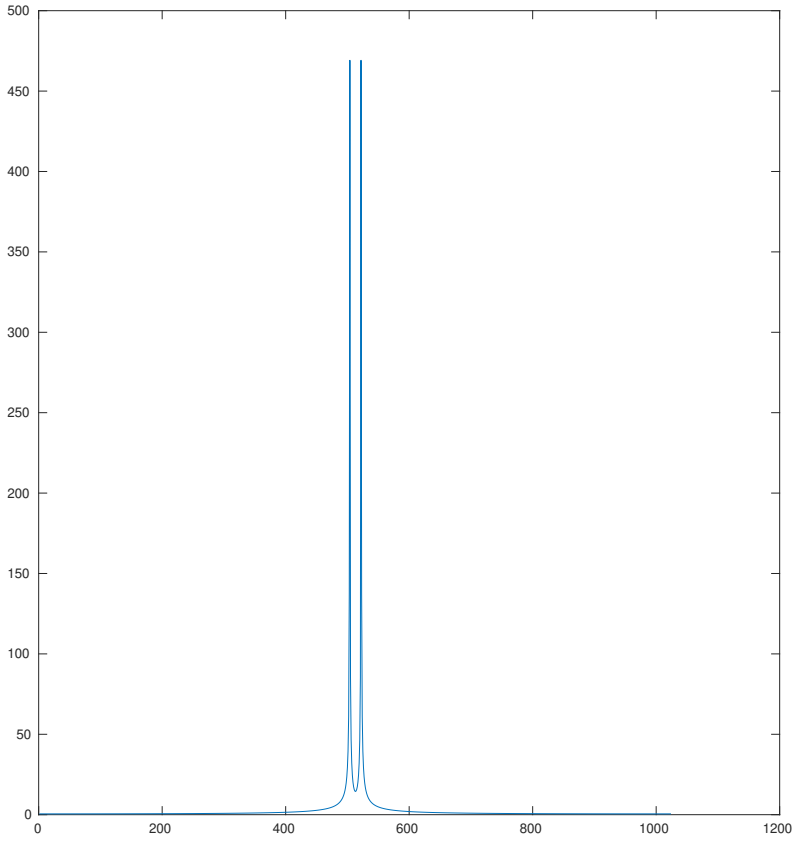
2.4 d

Sine wave with non-integer number of periods in window of 1024

2.4.1 Signal plot



2.4.2 Magnitude FFT

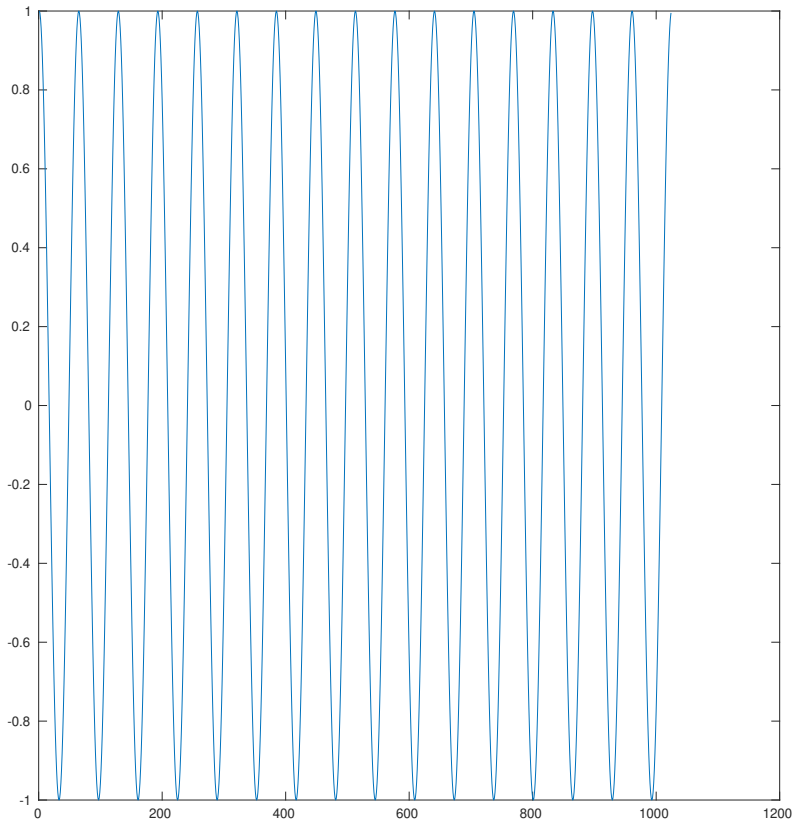


Locations of the peak = 8

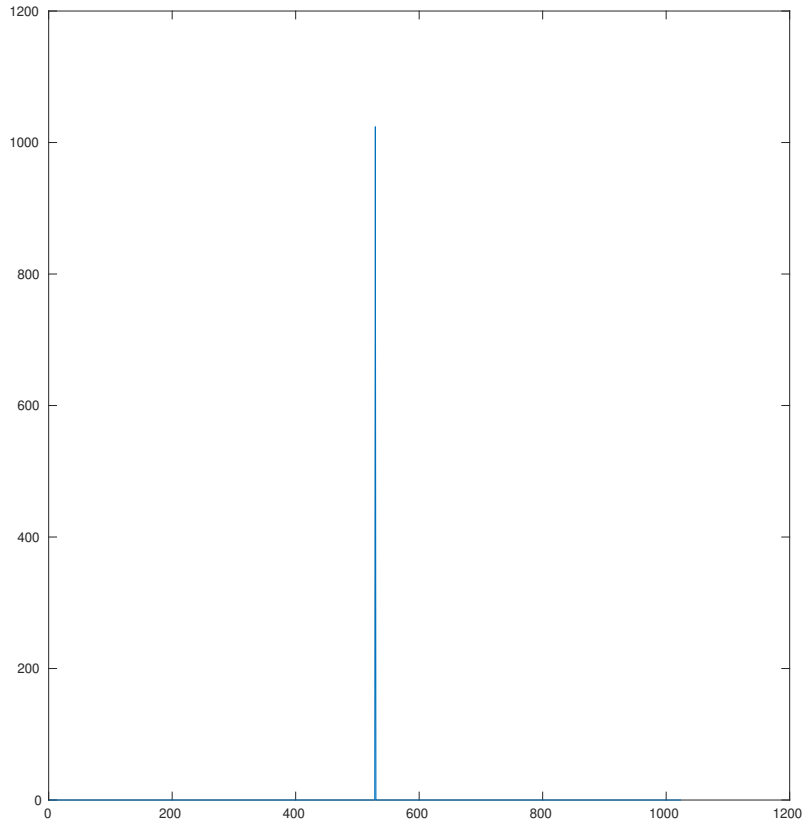
2.5 e

thetac = .. n = 0:1023; xe = exp(1i*thetac*n); plot(real(xe));

2.5.1 Signal plot



2.5.2 Magnitude FFT

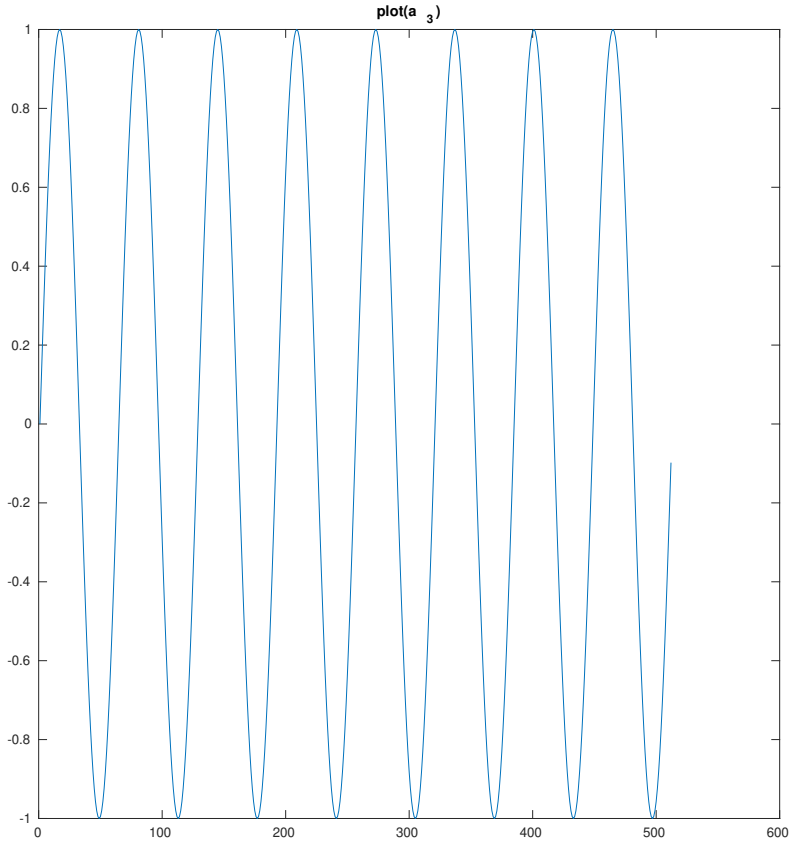


$N_0 = 64$ We can observe only one peak. Number of peaks does not change if we change the value of θ_c

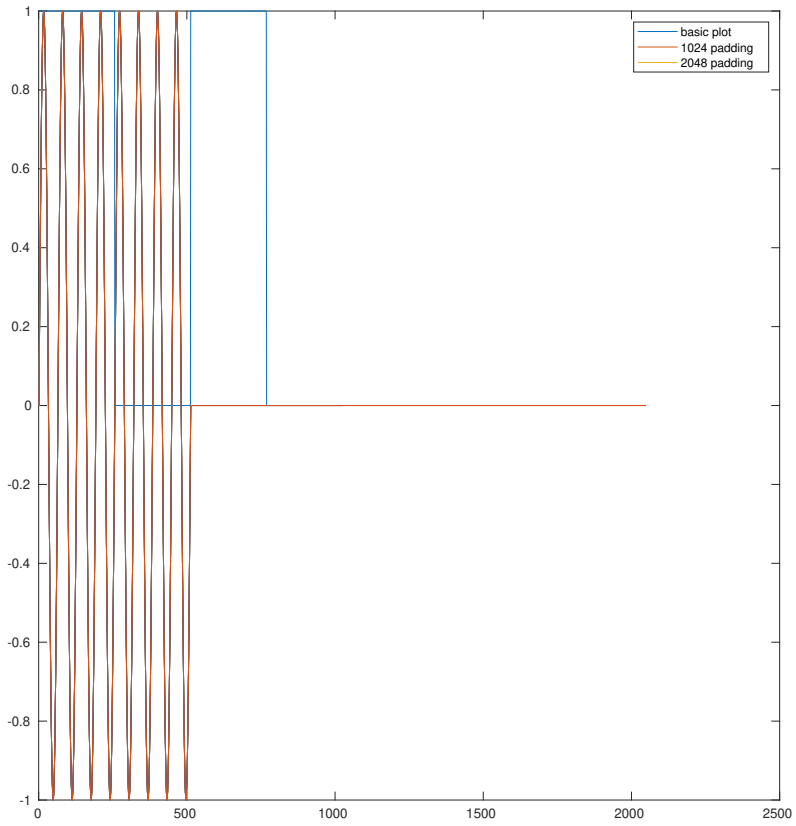
Chapter 3

Task 3

3.0.1 Original sine wave plot

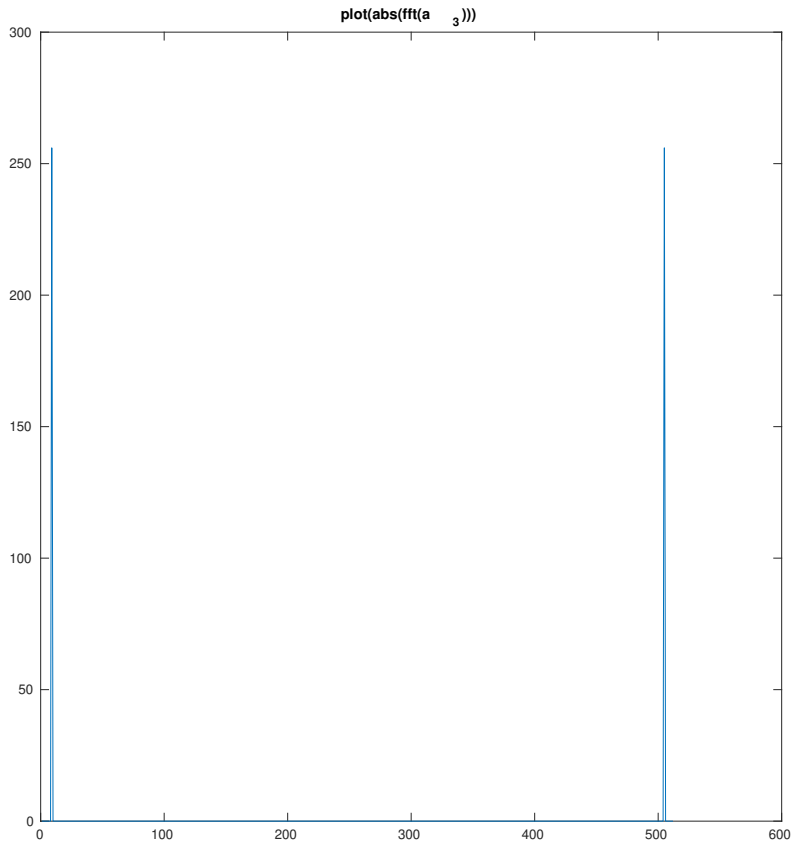


3.0.2 Zero pad of sine wave to 1024 and 2048 samples

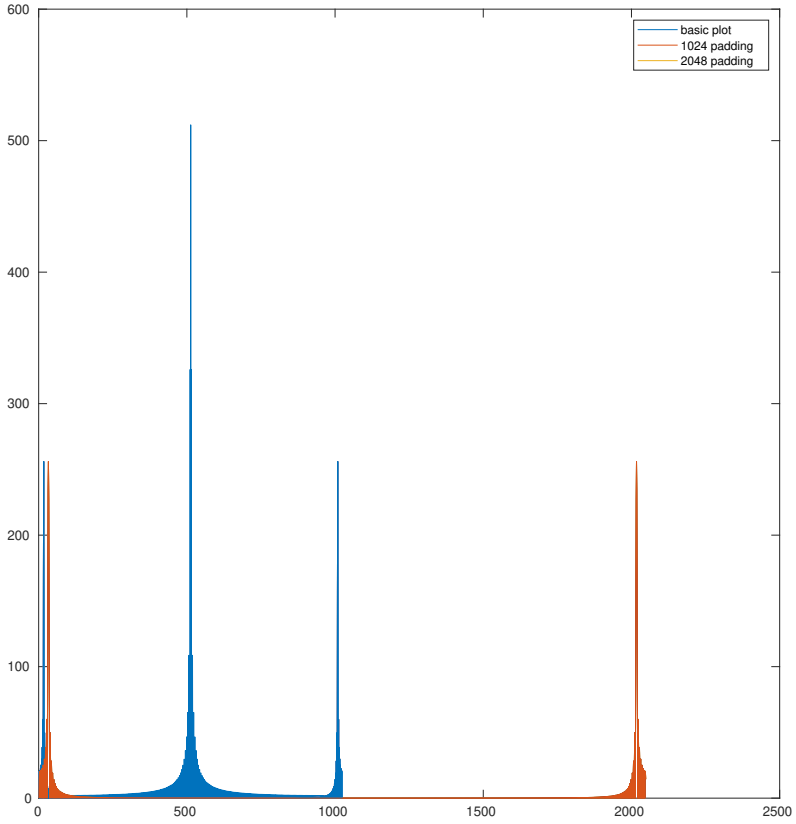


The signals are zero-padded therefore they overlap and we can more or less see only one of them.

3.0.3 abs(fft()) of original signal

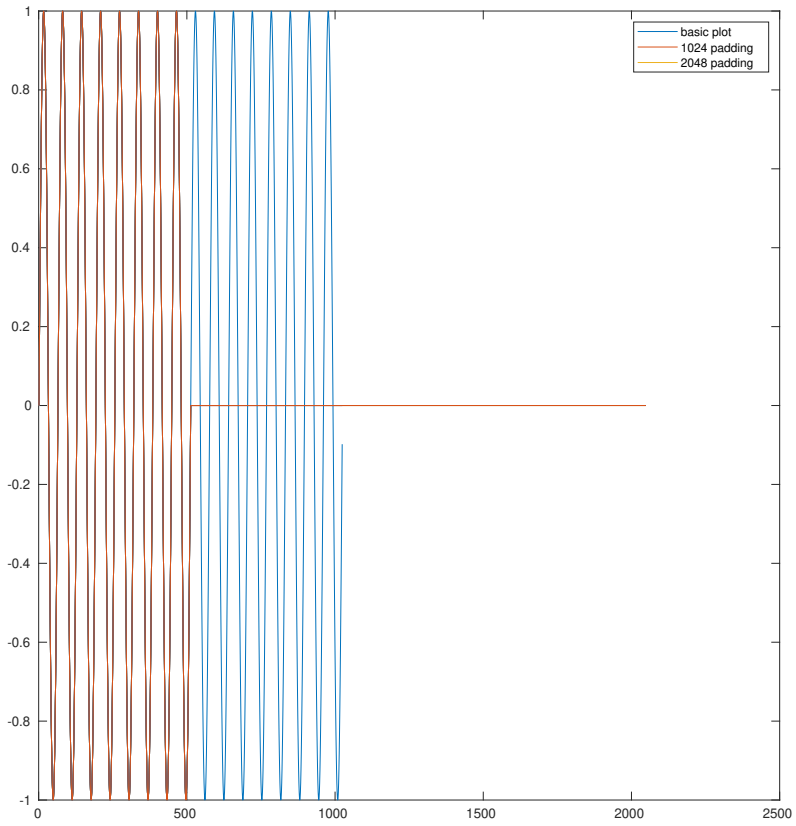


3.0.4 Zero pad of abs(fft())



Peak widths: basic peak width = 505 - 9 = 496; 1024 padding peak width = 1009 - 17 = 992 2048 padding peak width = 2017 - 33 = 1984

3.0.5 Real part of IFFT

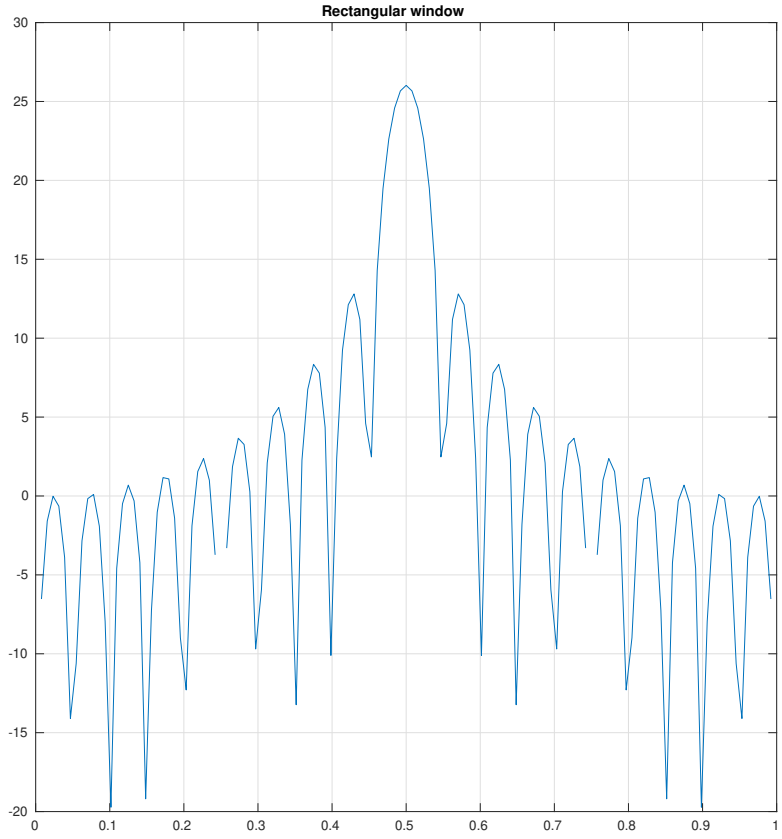


This time signals do not overlap! Therefore we can conlude that there is quite a difference between this and original signal.

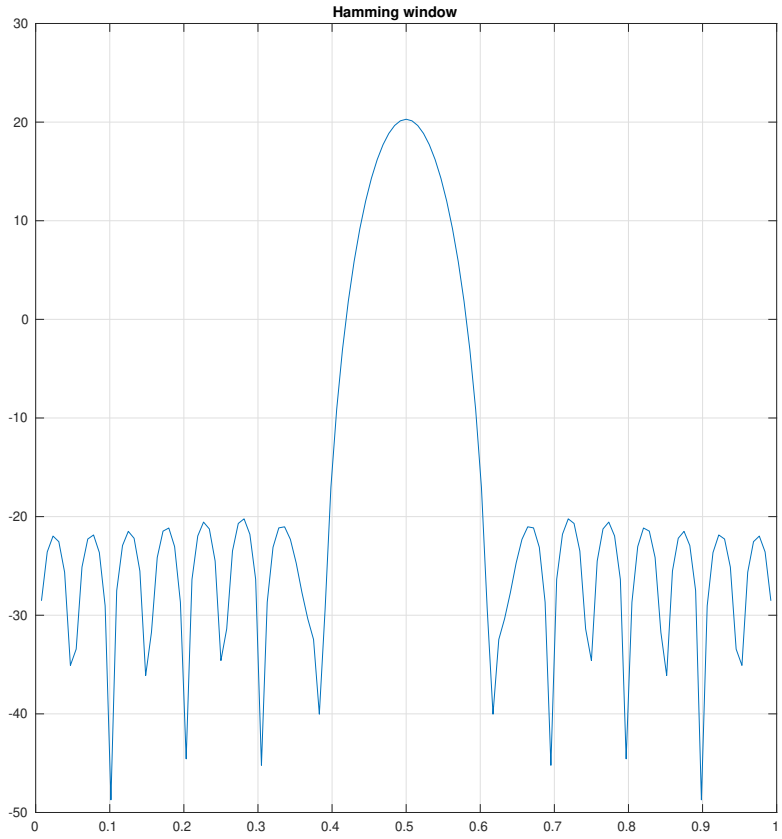
Chapter 6

Task 6

6.1 Rectangular window



6.2 Hamming window



6.3 Table

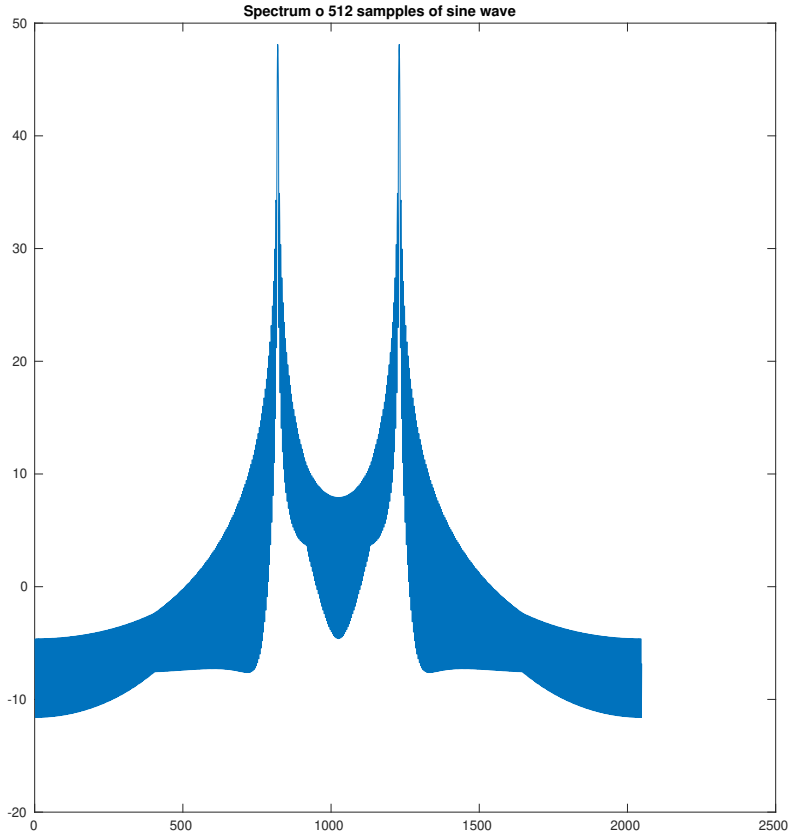
Window type	Mainlobe width	First sidelobe	Highest sidelobe
Rectangular	0.09	13.21	12.80
Hamming	0.23	41.32	- 20.22

Sidelobs change with f: SIdelobe is much wider in Hamming than in rectangular window

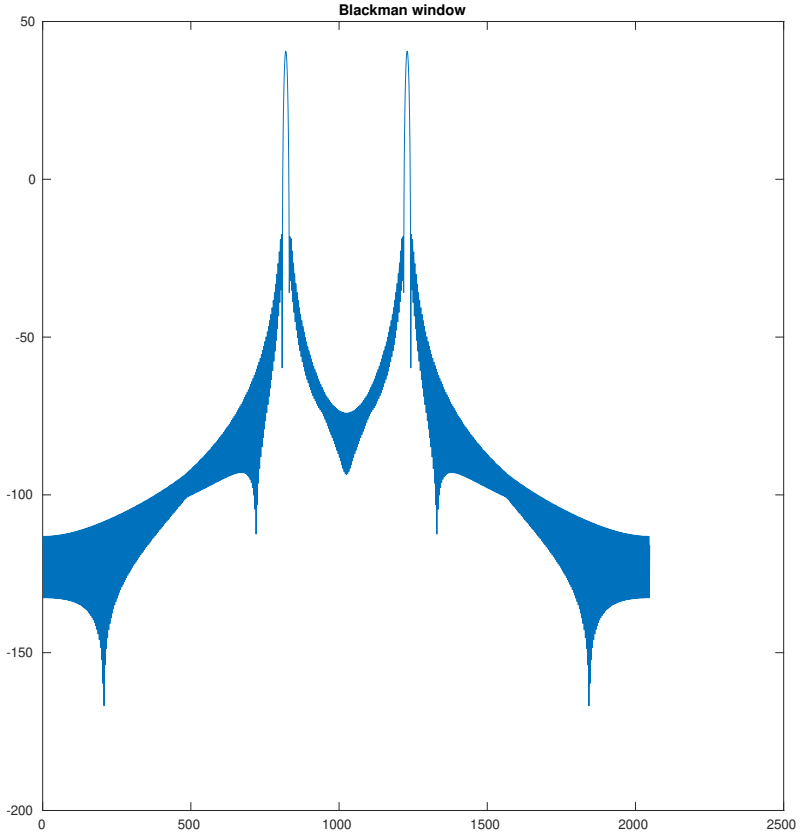
Chapter 7

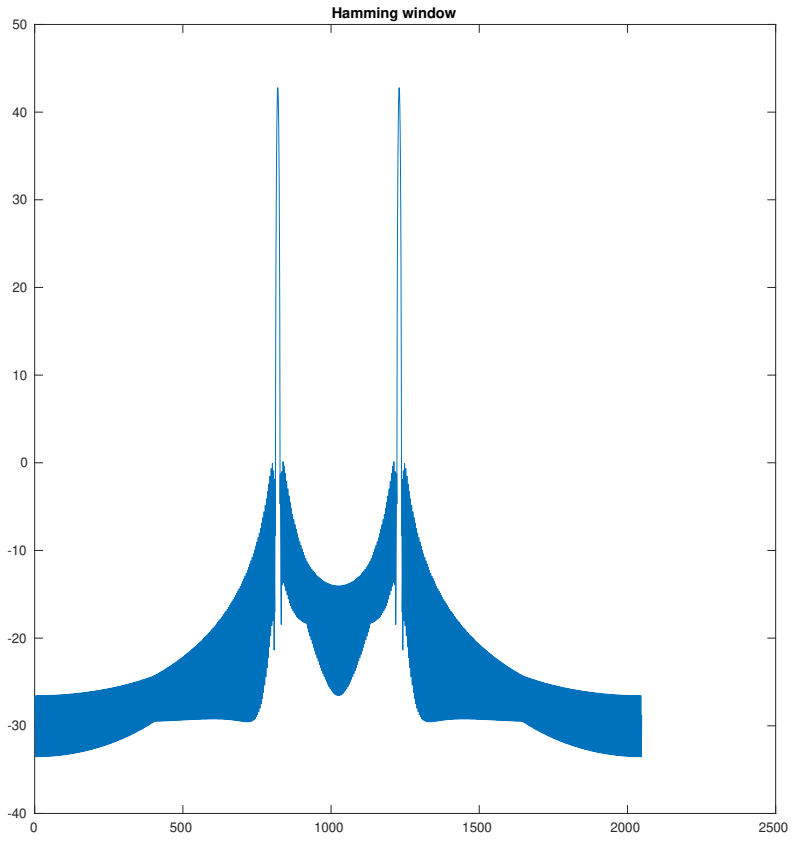
Task 7

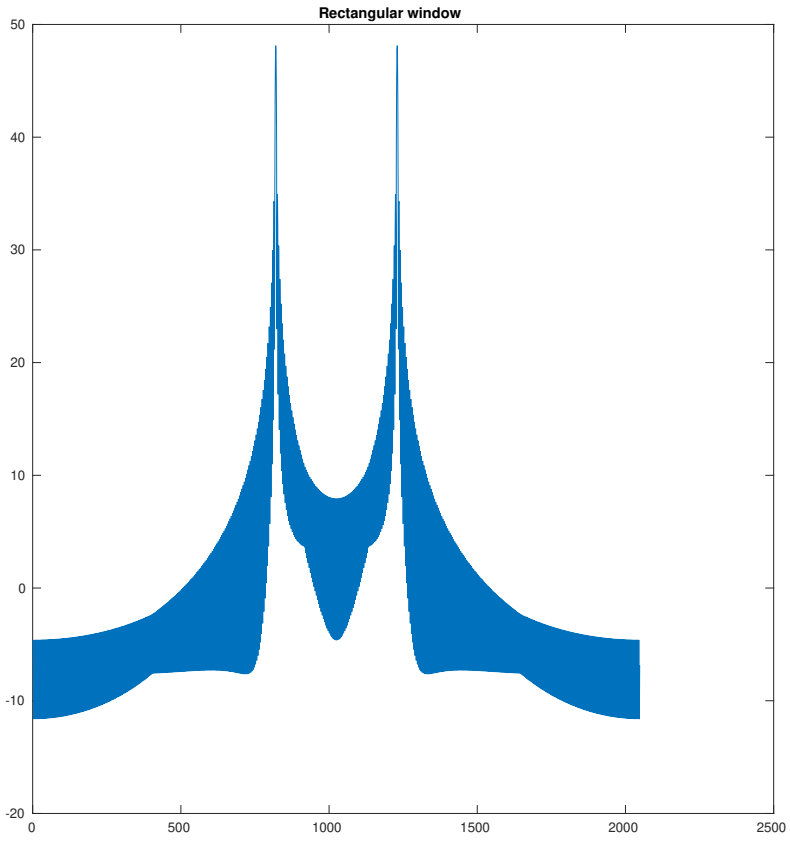
7.1 a) Spectrum of 512 samples of sine wave

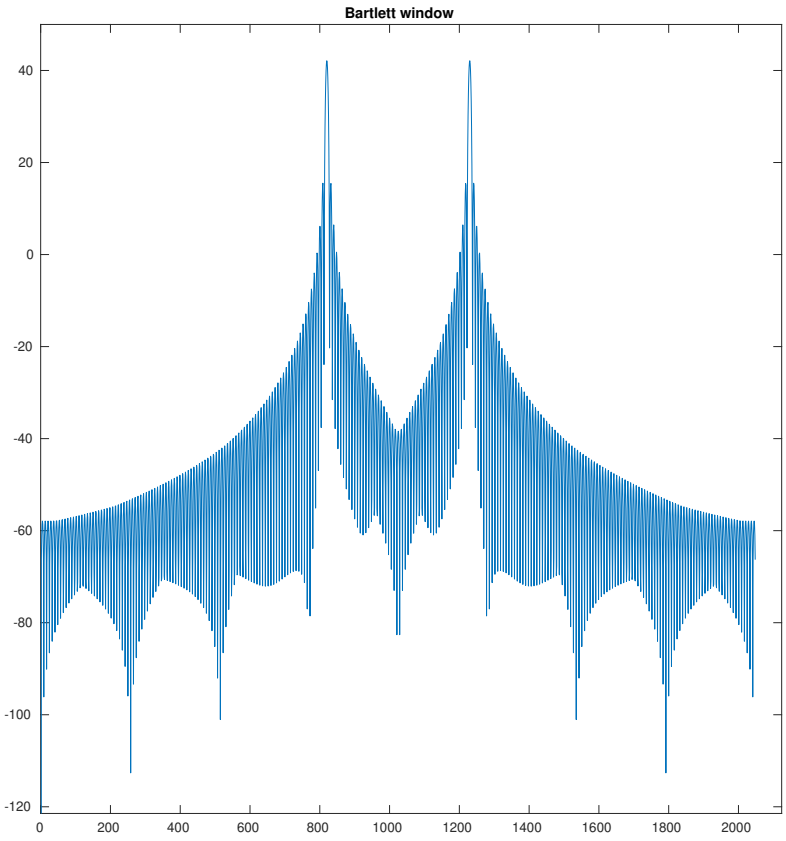


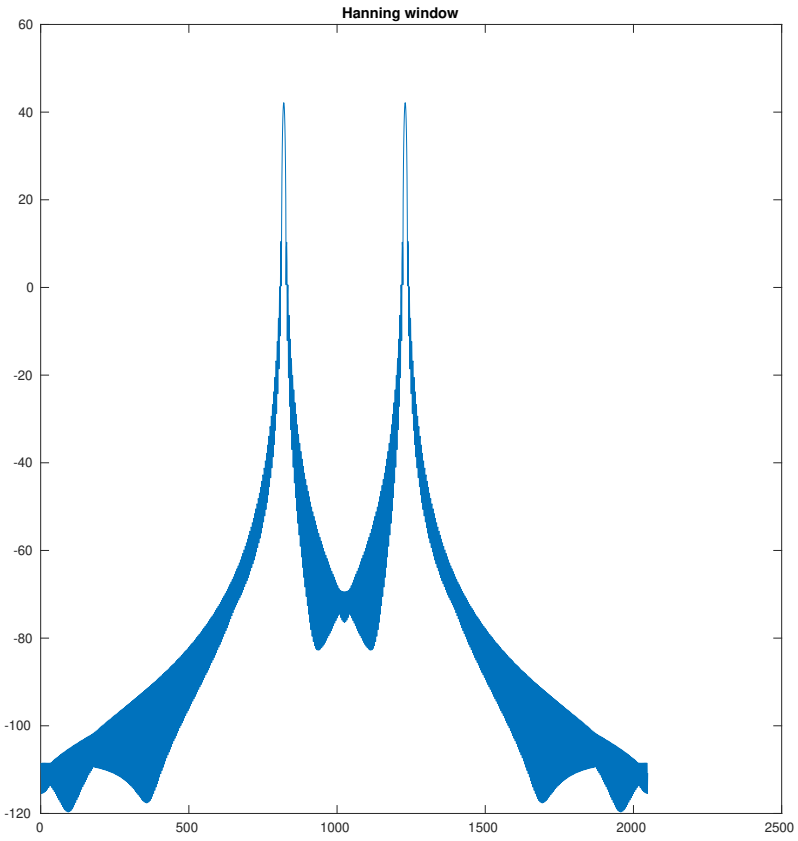
7.2 b) Use different window shapes to obtain good, clear plot of the spectrum

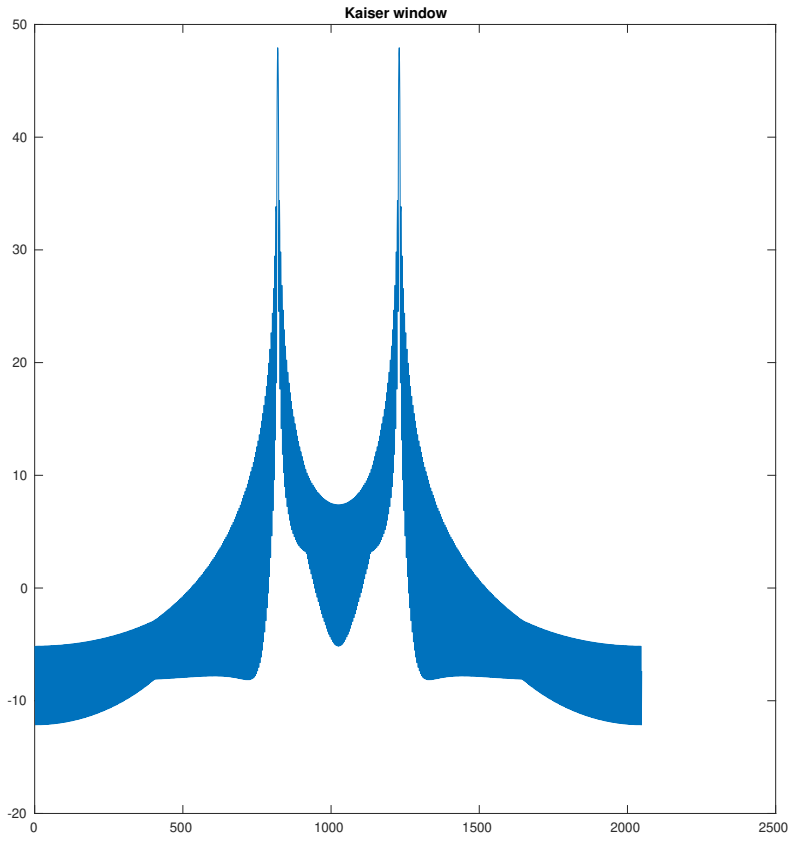



Hamming window
50
40
30
20
10
0
-10
-20
-30
-40
0
500
1000
1500
2000
2500


Rectangular window
50
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500

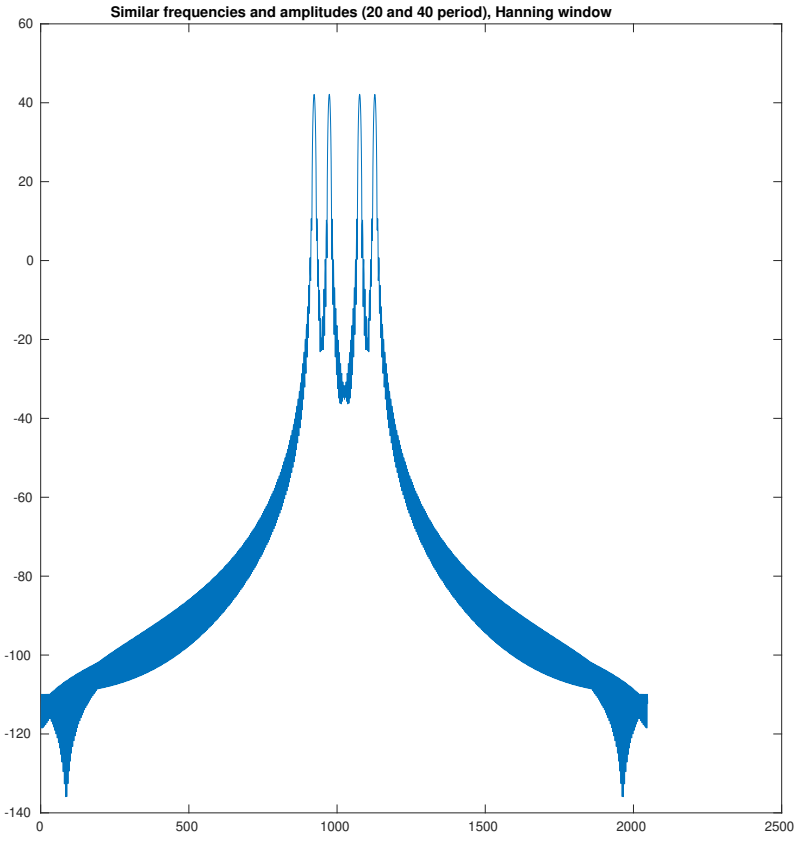

Bartlett window
40
20
0
-20
-40
-60
-80
-100
-120
0
200
400
600
800
1000
1200
1400
1600
1800
2000

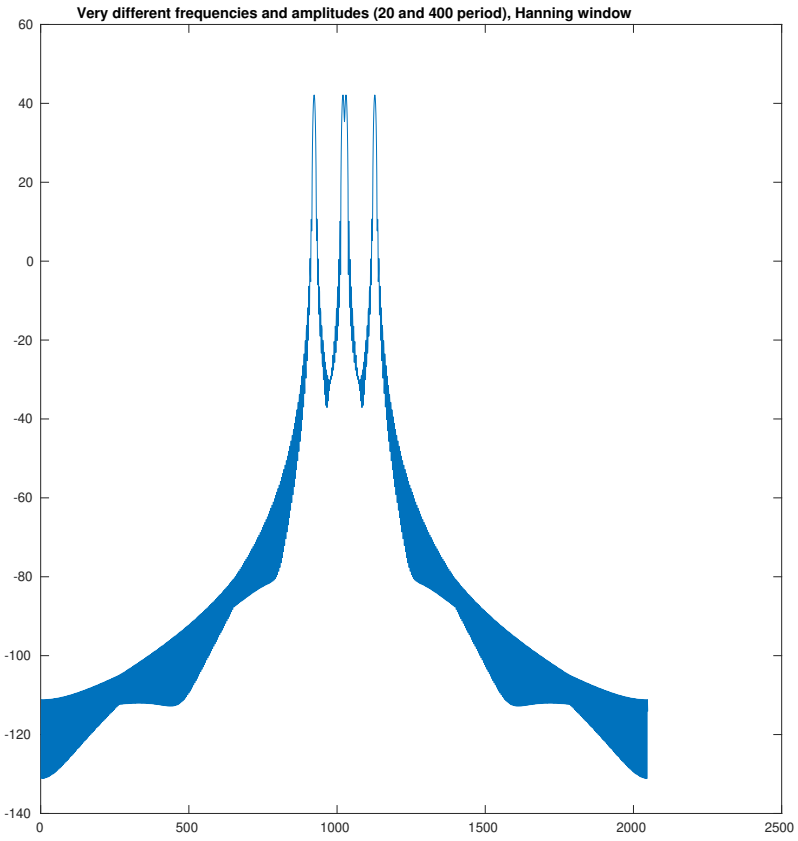

Hanning window
60
40
20
0
-20
-40
-60
-80
-100
-120
0
500
1000
1500
2000
2500


Kaiser window
50
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500

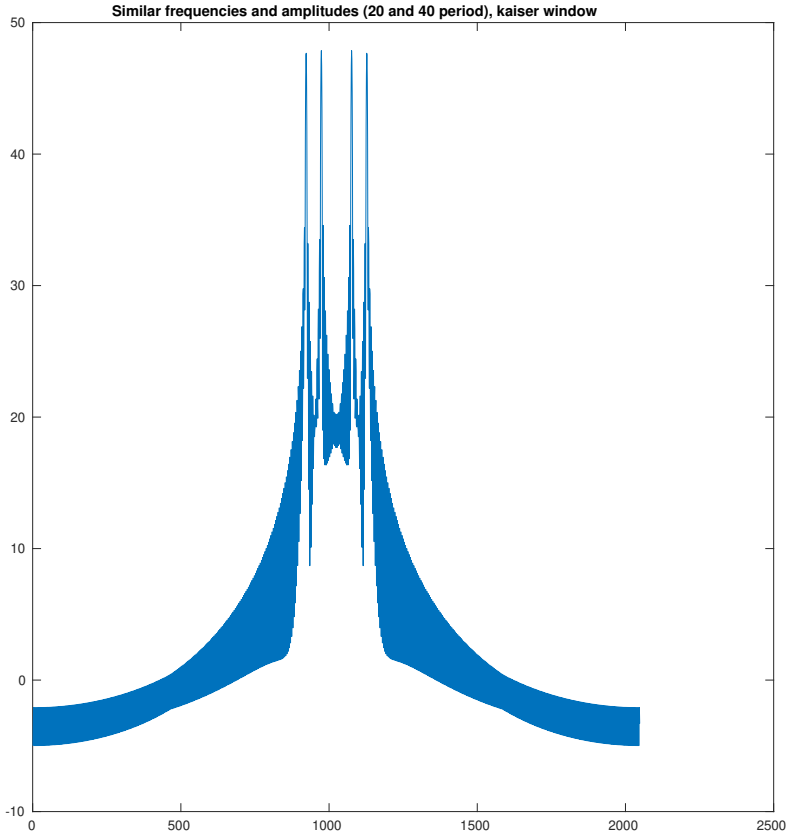
7.3 Signal seperation properties of different windows

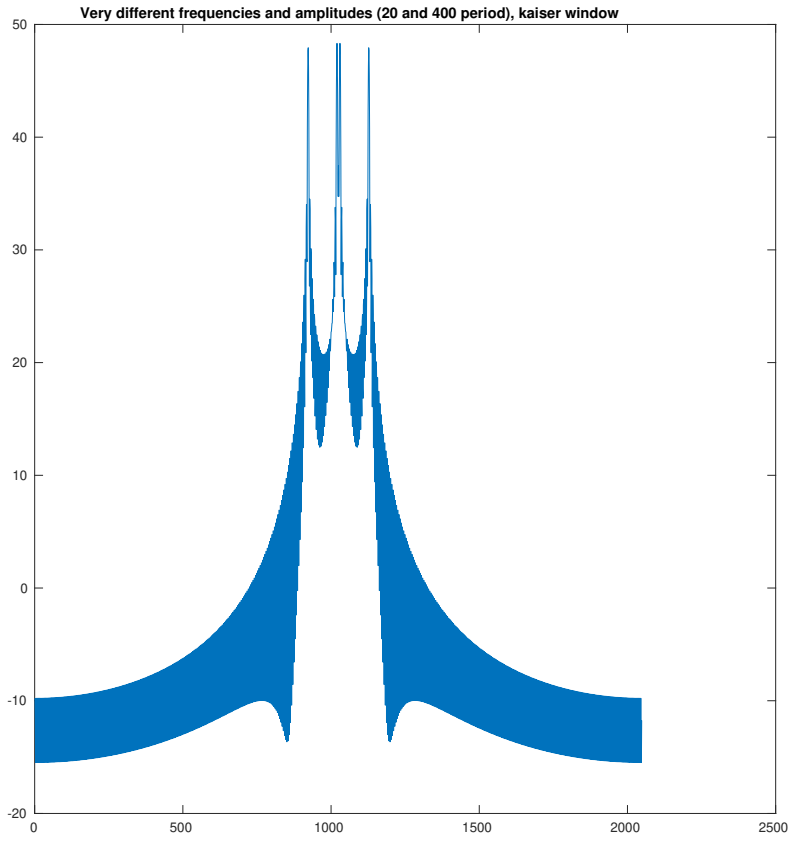
7.3.1 Hanning



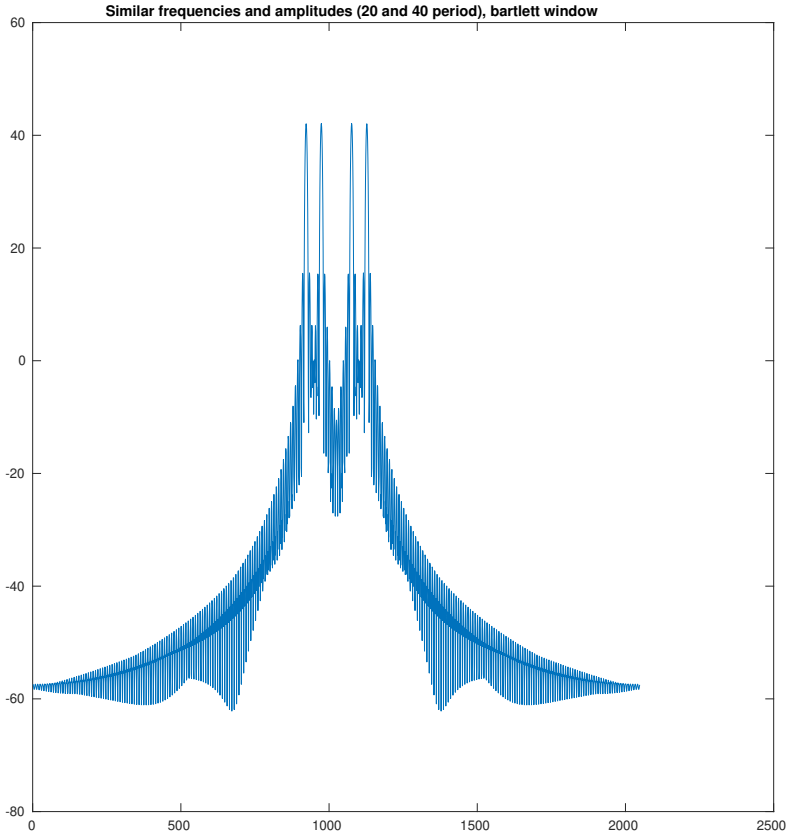

Very different frequencies and amplitudes (20 and 400 period), Hanning window
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
0
500
1000
1500
2000
2500

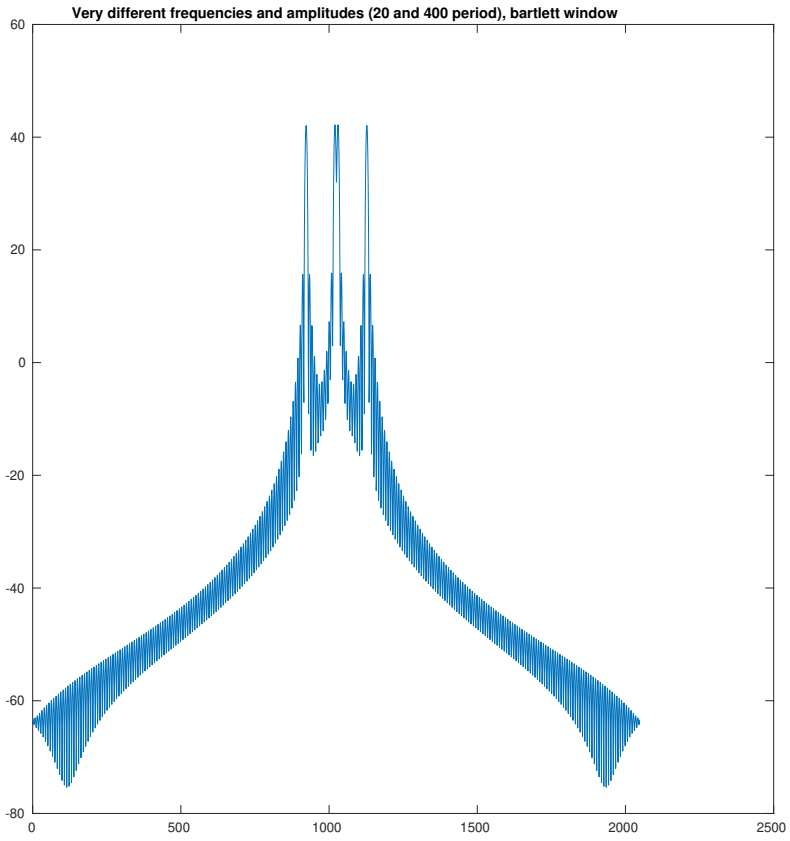
7.3.2 Kaiser


Similar frequencies and amplitudes (20 and 40 period), kaiser window
50
40
30
20
10
0
-10
0
500
1000
1500
2000
2500

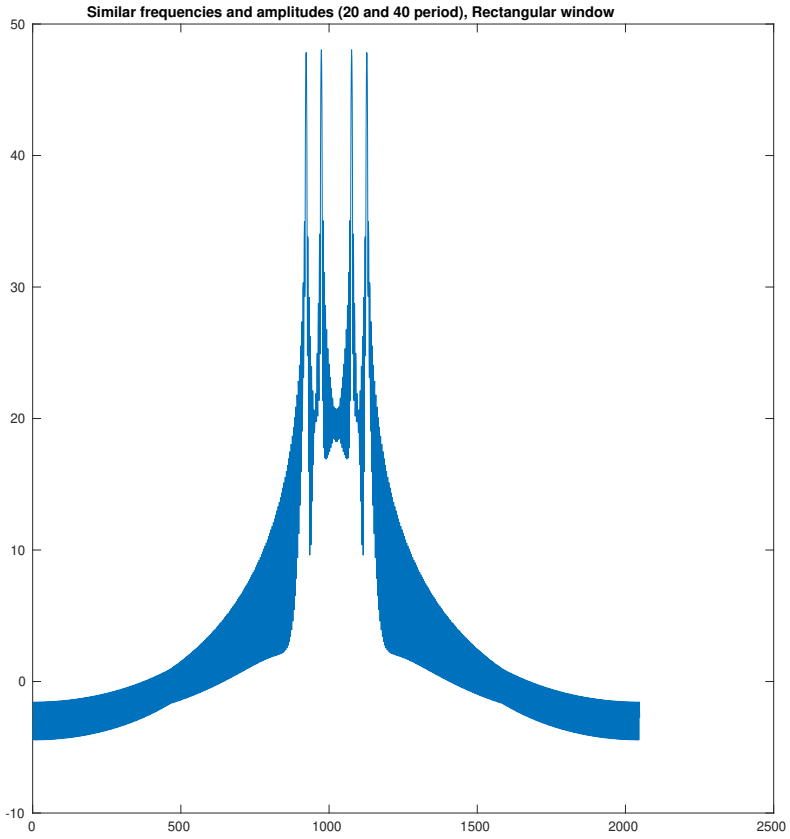

Very different frequencies and amplitudes (20 and 400 period), kaiser window
50
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500

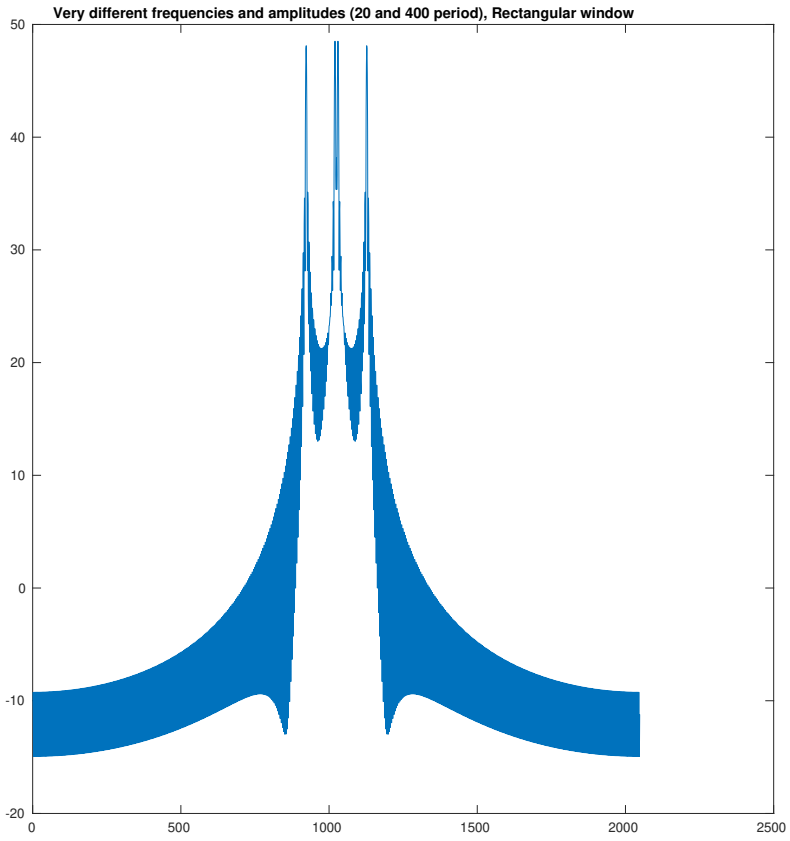
7.3.3 Bartlett



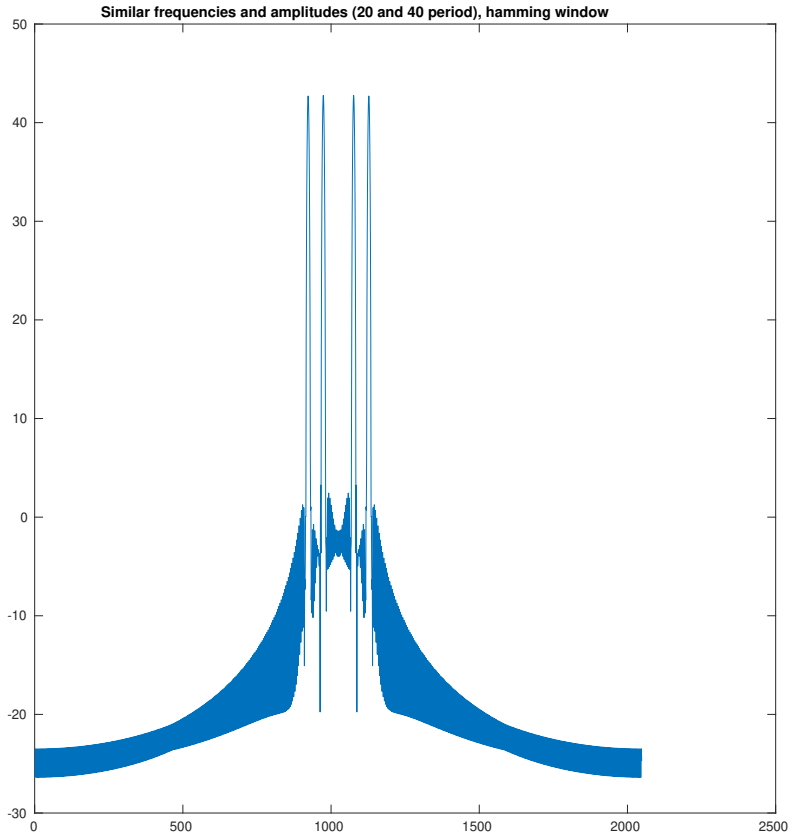

Very different frequencies and amplitudes (20 and 400 period), bartlett window
60
40
20
0
-20
-40
-60
-80
0
500
1000
1500
2000
2500

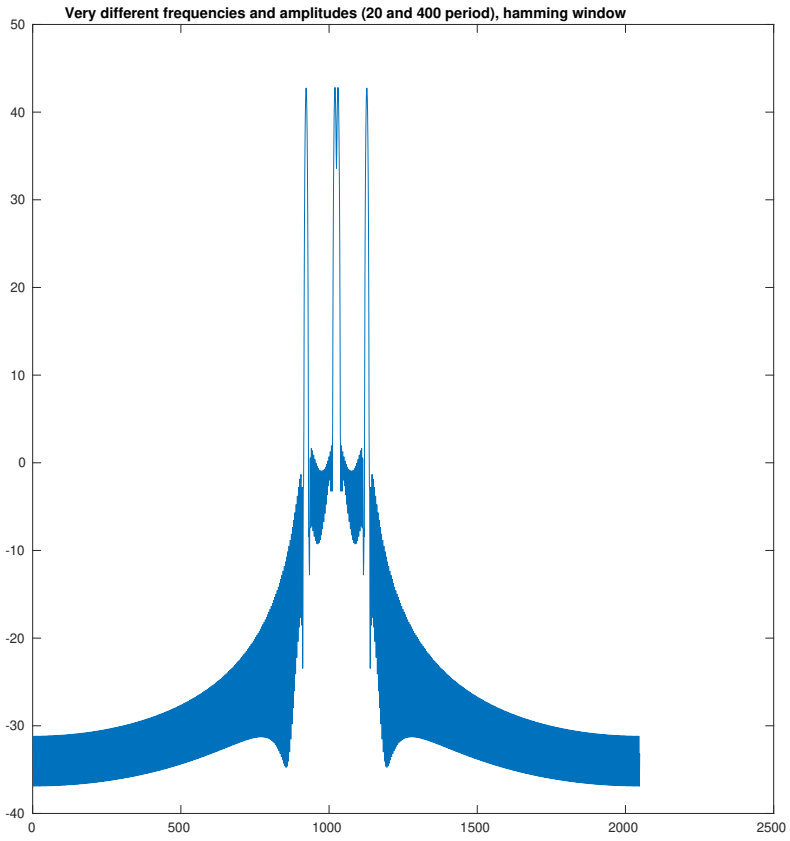
7.3.4 Rectangular



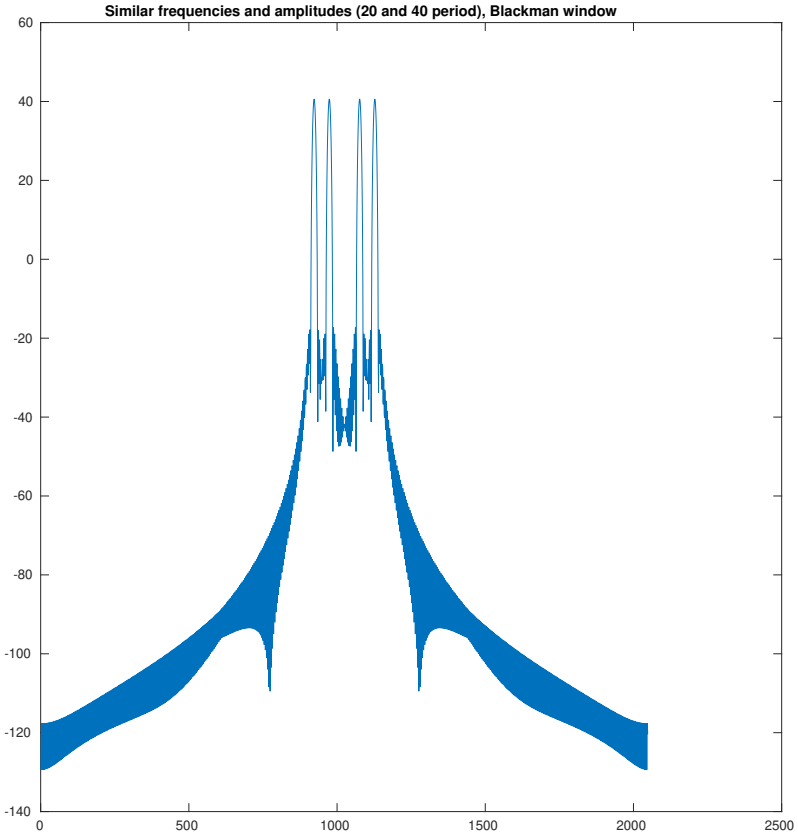

Very different frequencies and amplitudes (20 and 400 period), Rectangular window
50
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500

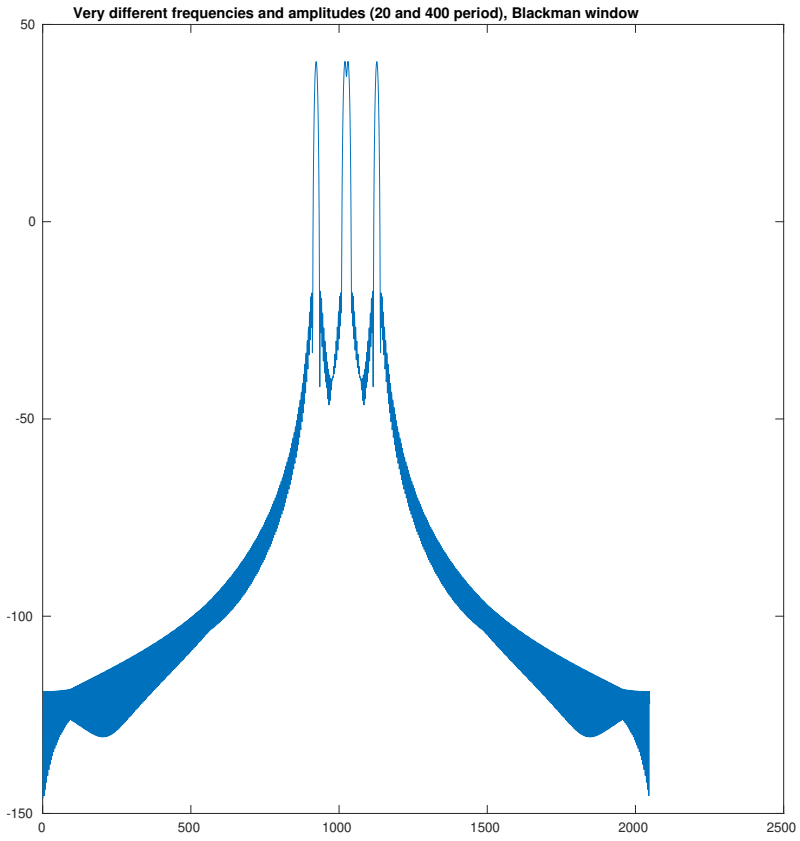
7.3.5 Hamming


Similar frequencies and amplitudes (20 and 40 period), hamming window
50
40
30
20
10
0
-10
-20
-30
0
500
1000
1500
2000
2500


Very different frequencies and amplitudes (20 and 400 period), hamming window
50
40
30
20
10
0
-10
-20
-30
-40
0
500
1000
1500
2000
2500

7.3.6 Blackman




Very different frequencies and amplitudes (20 and 400 period), Blackman window
50
0
-50
-100
-150
0
500
1000
1500
2000
2500