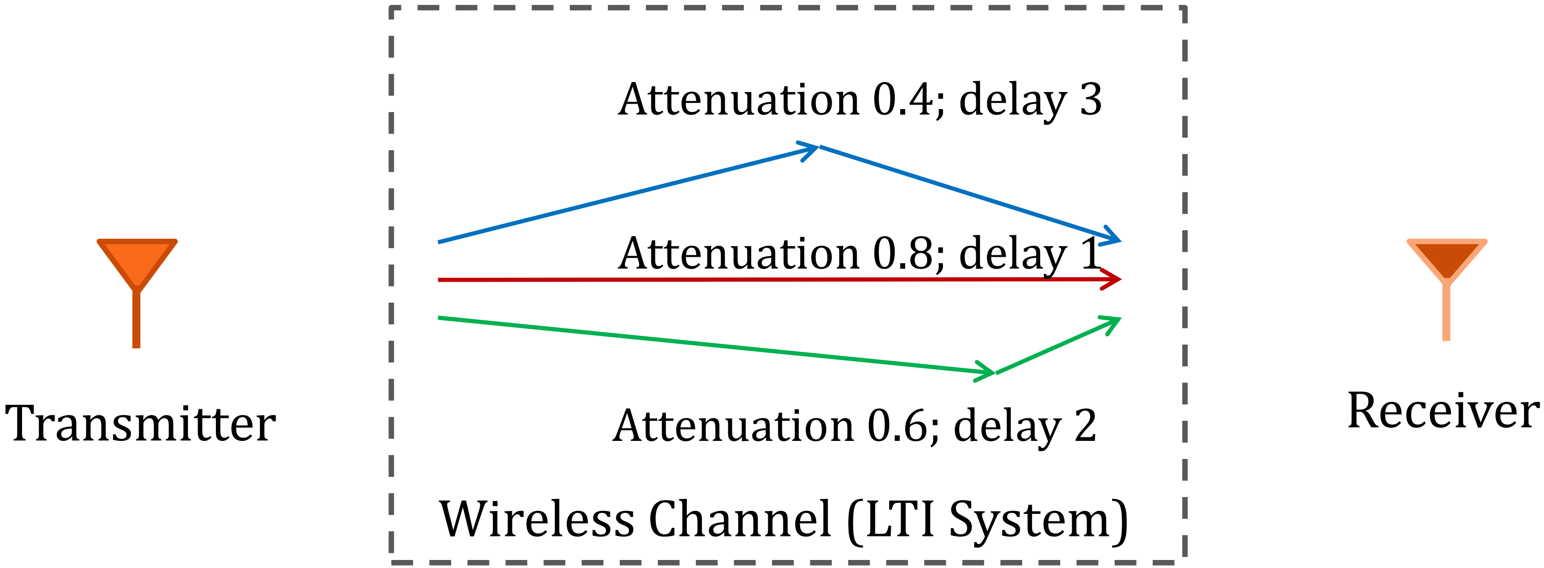
Designing a wireless signal detector via Matlab.

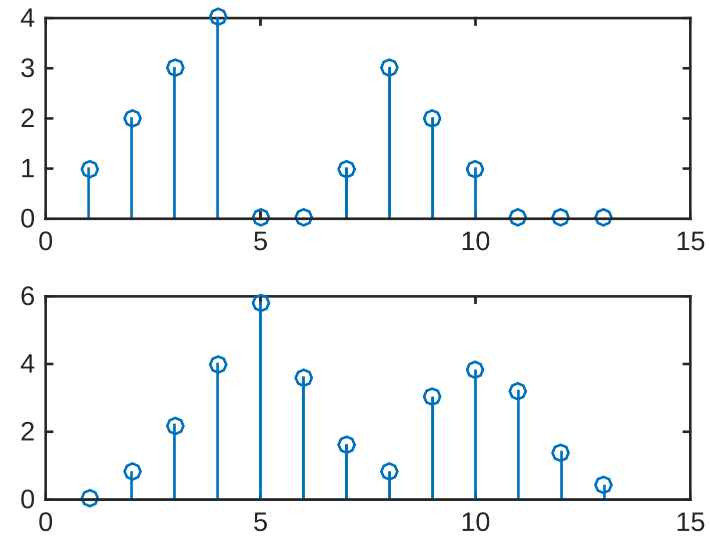
Example: Simplified Wireless Channel



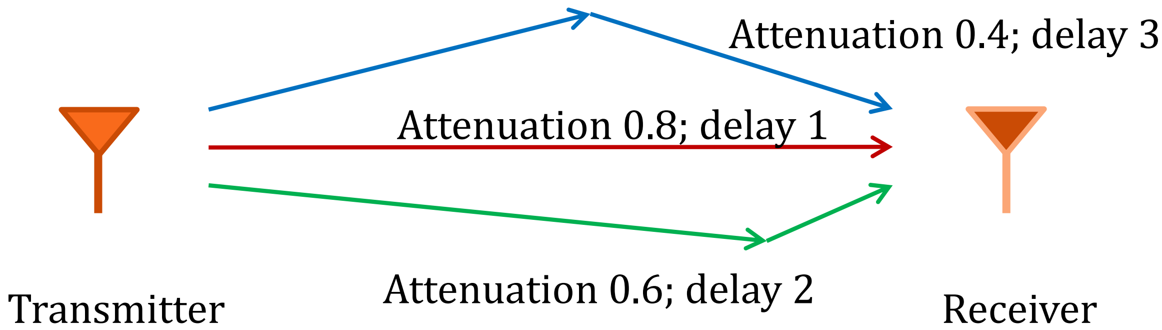
Difference equation: $y[n] = 0.8x[n-1] + 0.6x[n-2] + 0.4x[n-3]$

Impulse response: $h_1[n] = 0.8\delta[n-1] + 0.6\delta[n-2] + 0.4\delta[n-3]$

- Generate Tx signal:
  - x=[1 2 3 4 0 0 1 3 2 1 0 0 0];
- Generate Rx signal:
  - A1 = 1;
  - B1 = [0 0.8:-0.2:0.4];
  - y = filter(B1, A1, x);
  - subplot(2,1,1), stem(x);
  - subplot(2,1,2), stem(y);



Signal detection: How to recover the transmission signal from the received signal?



Wireless Channel

$$y[n] = 0.8x[n-1] + 0.6x[n-2] + 0.4x[n-3]$$

Detected Signal
$z[n] = x[n]$ or
$z[n] = x[n-k]$

Signal Detector
(LTI System)

Received Signal
$y[n]$

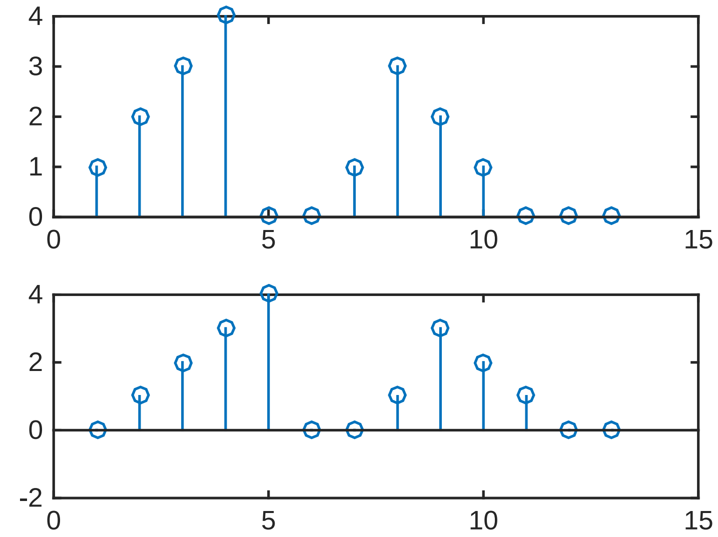
Impulse response: $h_2[n] * h_1[n] = \delta[n]\ or\ \delta[n-k]$ 非因果，z[n-1]的值取决于y[n]

Difference Equation: $0.8z[n-1] + 0.6z[n-2] + 0.4z[n-3] = y[n]$

$$z'[n] = z[n-1] \Rightarrow 0.8z'[n] + 0.6z'[n-1] + 0.4z'[n-2] = y[n]$$

- Generate detected signal:

```
• A2 = 0.8:−0.2:0.4;
• B2 = 1;
• z = filter(B2, A2, y);
```



- Compare the two signals:

```
• subplot(2,1,1); stem(x);
• subplot(2,1,2); stem(z);
```

- Lab assignment 2.10
  - Echo Cancellation via Inverse Filtering.
    - (a)-(e)
    - (e) conv(he, her) is not a unit impulse, why?
  - Besides of inverse filtering, the concept of auto-correlation is introduced.
    - (f)

Signal Auto-Correlation

- Auto-correlation of u[n]: $w[n] = u[n] * u[-n]$

翻转

```
u=randn(1,40);
nu = 1:40;
v=u(end:-1:1);
nv=-40:-1;
w=conv(u,v);
nw=nu(1)+nv(1):nu(end)+nv(end);
stem(nw,w)
```

'fliplr' or 'filpud'

左右翻 行向量

上下翻 列向量

Auto-correlation of a random signal has a high peak at the origin

Lab assignment 2.10(f)

Suppose that you were given $y[n]$ but did not know the value of the echo time, N, or the amplitude of the echo, α. Based on Eq. (2.21), can you determine a method of estimating these values? Hint: Consider the output y of the echo system to be of the form:

$$y[n] = x[n] * (\delta[n] + \alpha\delta[n-N])$$

and consider the signal,

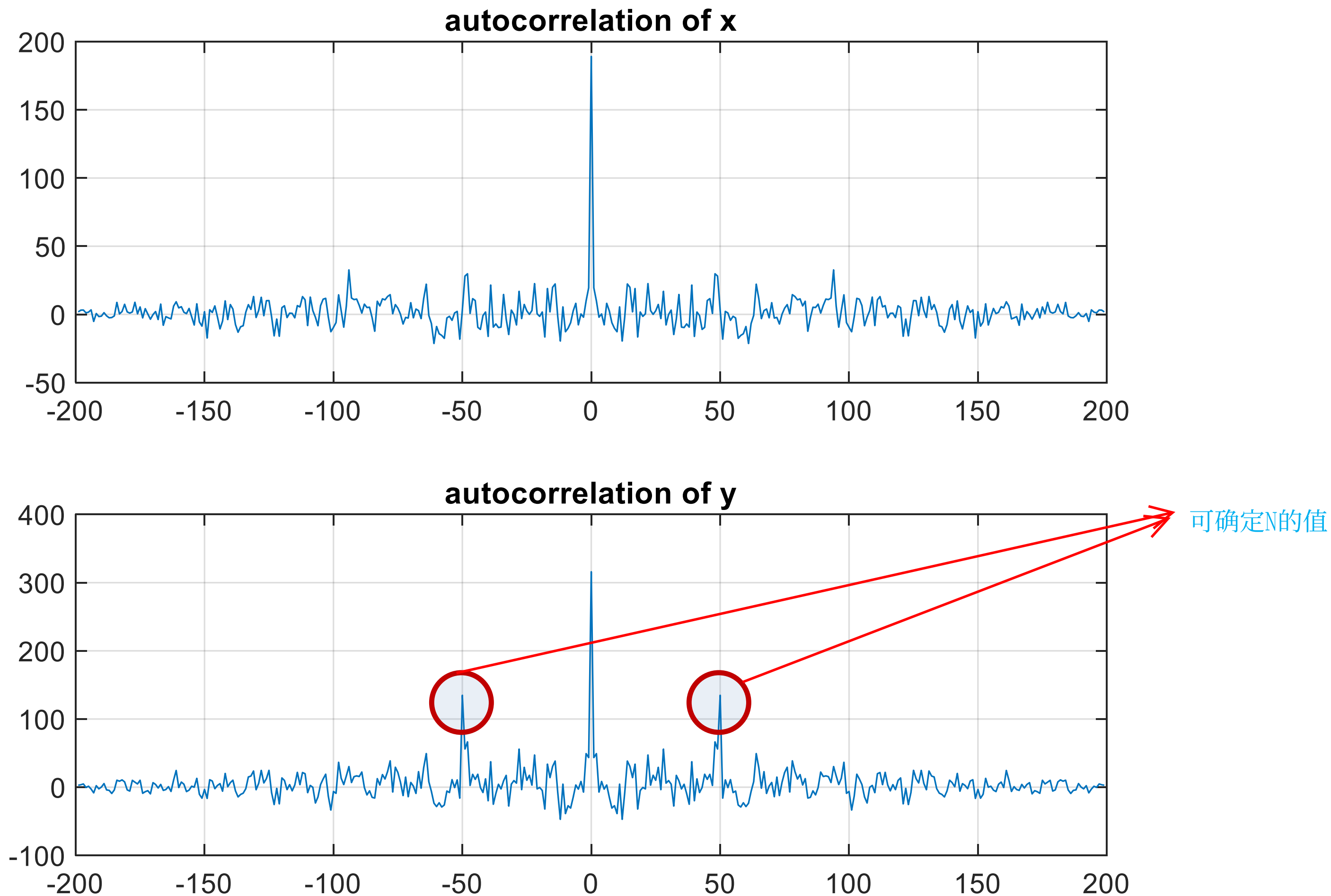
$$R_{yy}[n] = y[n] * y[-n].$$

This is called the autocorrelation of the signal $y[n]$ and is often used in applications of echo-time estimation. Write $R_{yy}[n]$ in terms of $R_{xx}[n]$ and also plot $R_{yy}[n]$. You will

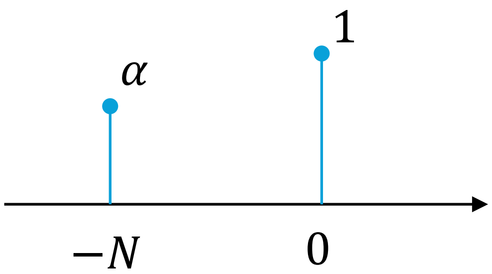
$$\boxed{\begin{aligned} y[n] &= x[n] + \alpha x[n-N] \\ &= x[n] * (\delta(n) + \alpha\delta(n-N)) \end{aligned}}$$

$$\begin{aligned} R_{yy}[n] &= x[n] * (\delta[n] + \alpha\delta[n-N]) * x[-n] * (\delta[n] + \alpha\delta[n+N]) \\ &= R_{xx} * ((1+\alpha^2)\delta[n] + \alpha\delta[n-N] + \alpha\delta[n+N]) \end{aligned}$$

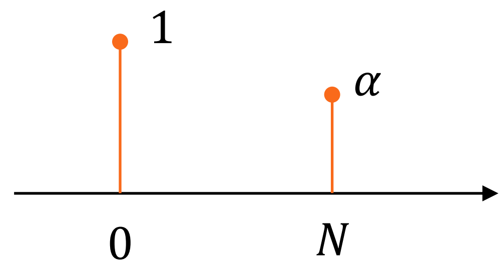
- NX = 200;
- x = randn(1,NX);
- N =50;
- alpha = 0.9;
- yex = filter([1,zeros(1,N-1),alpha],1,x);
- Rxx = conv(x,fliplr(x));
- Ryy = conv(yex,fliplr(yex));
- figure;subplot(212);plot([-NX+1:NX-1],Ryy); grid on; title('autocorrelation of y');
- subplot(211);plot([-NX+1:NX-1],Rxx); grid on; title('autocorrelation of x');


autocorrelation of x
200
150
100
50
0
-50
-200
-150
-100
-50
0
50
100
150
200
autocorrelation of y
400
300
200
100
0
-100
-200
-150
-100
-50
0
50
100
150
200
可确定N的值

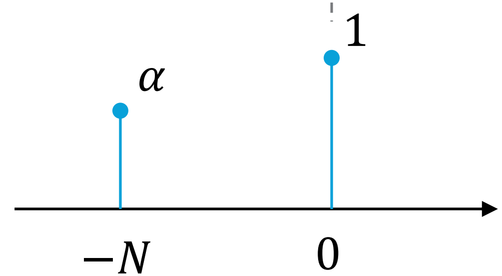
$$\boldsymbol{\delta[n] + \alpha\delta[n+N]}$$



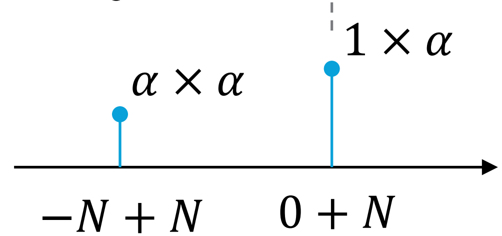
$$\boldsymbol{\delta[n] + \alpha\delta[n-N]}$$



$$\boldsymbol{(\delta[n] + \alpha\delta[n+N]) * \delta[n]}$$

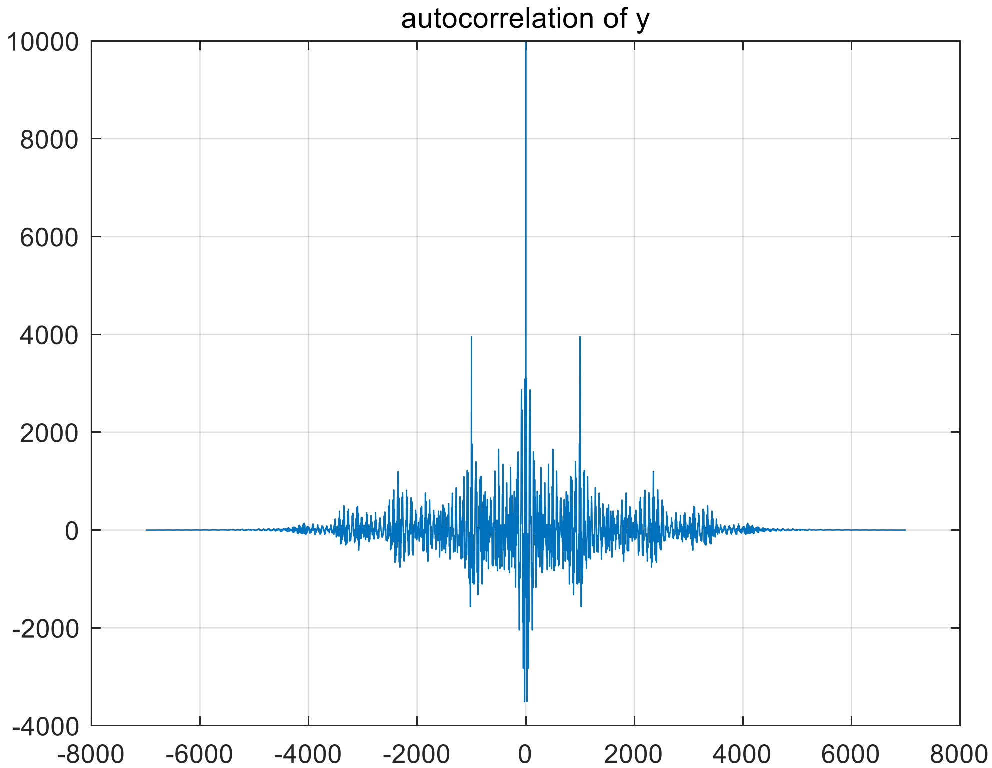


$$\boldsymbol{(\delta[n] + \alpha\delta[n+N]) * \alpha\delta[n-N]}$$



$$\boldsymbol{\alpha\delta[n+N] + (1+\alpha^2)\delta[n] + \alpha\delta[n-N]}$$

- For $y[n] = x[n] + \alpha x[n-N], \alpha = 0.5, N = 1000$
- The Auto-Correlation of $y[n]$



Lab Assignment 2 – part (b)

- 2.10
  - The sound file ‘lineup.mat’ for 2.10 will be uploaded to Blackboard

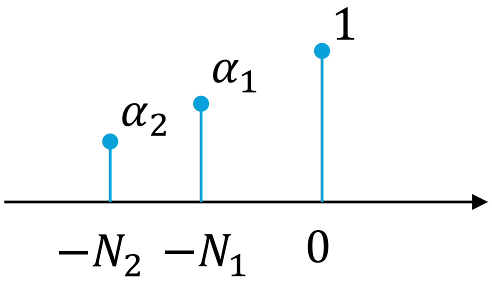
$$y_2[n] = x[n] + \alpha x[n - N], unknown\ \alpha\ and\ N$$

$$y_3[n] = x[n] + \alpha_1 x[n - N_1] + \alpha_2\, x[n - N_2]$$

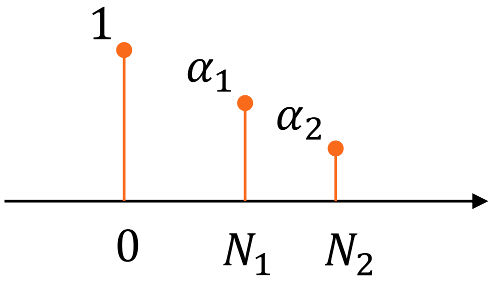
$$= x[n] * (\delta[n] + \alpha_1 \delta[n - N_1] + \alpha_2\, \delta[n - N_2])$$

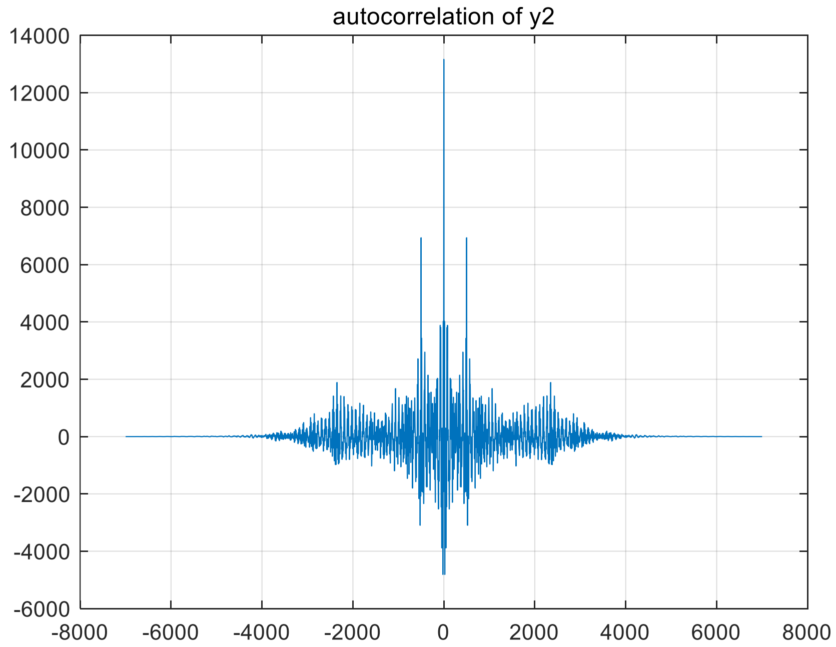
$$R_{y_3 y_3}[n] = y_3[n] * y_3[-n]$$

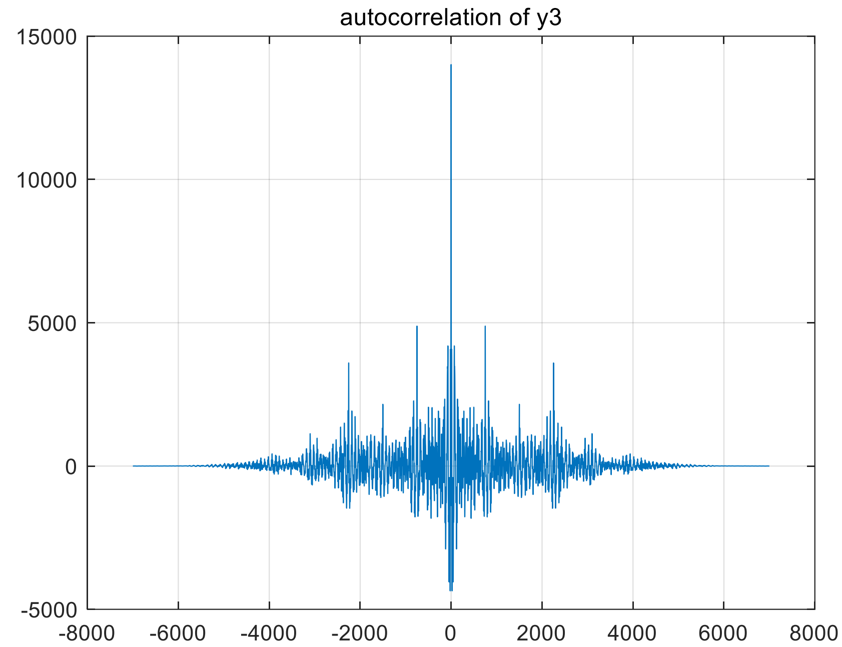
$$\boldsymbol{\delta[n] + \alpha_1\delta[n + N_1] + \alpha_2\delta[n + N_2]}$$



$$\boldsymbol{\delta[n] + \alpha_1\delta[n - N_1] + \alpha_2\delta[n - N_2]}$$




autocorrelation of y2
14000
12000
10000
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
-6000
-4000
-2000
0
2000
4000
6000
8000


autocorrelation of y3
15000
10000
5000
0
-5000
-8000
-6000
-4000
-2000
0
2000
4000
6000
8000

Lab Assignment 2 – All

- Read tutorial 2.1 & 2.2 by yourself
- 2.4, 2.5 & 2.10 y2和y3求解过程中不能用到关于z的任何信息
  - The sound file 'lineup.mat' for 2.10 will be uploaded to Blackboard
- Submit your report + codes onto Blackboard before 10:00 am Oct. 21st (week 6)

Practice

$$System\ \#1: y[n] = 0.8x[n-1] + 0.6x[n-2] + 0.4x[n-3]$$

$$System\ \#2: y[n] = \frac{x[n-2] + x[n-3] + x[n-4] + x[n-5]}{4}$$

- x=[1:10,9:-1:1];
- A1 = 1;
- B1 = [0 0.8:-0.2:0.4];
- y = filter(B1, A1, x);
- figure;stem(x);hold on
- stem(y,'r'); legend('input x', 'output y')
- A2 = 0.8:-0.2:0.4;
- B2 = 1;
- z = filter(B2, A2, y);
- figure; stem(x); grid on; hold on
- stem(z,'k'); legend('input x', 'detected z')

1. The code is to feed the system #1 with input signal x and get the output y, then design the inverse system to get a recovery version of x, signal z
2. Perform the same process to system #2 by replacing the red lines.

单选题 100分

设置

Coefficient vectors A2 and B2 for the inverse system of system #2 are

$$System\ \#2:\ y[n] = \frac{x[n-2] + x[n-3] + x[n-4] + x[n-5]}{4}$$

A $A2 = 1;\ \ B2 = [0,0,1,1,1,1]/4$

B $A2 = [0,0,1,1,1,1]/4;\ \ B2 = 1$

C $A2 = 1;\ \ B2 = [1,1,1,1]/4$

D $A2 = [1,1,1,1]/4;\ \ B2 = 1$

这同时是一次点名

提交

Any questions?