# 统计信号处理　实验一

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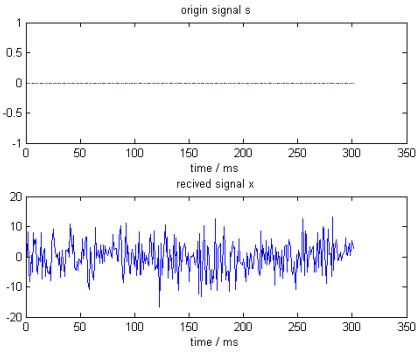
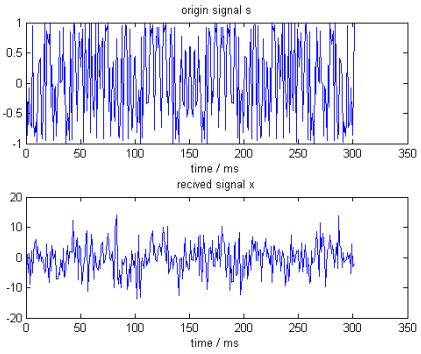
## 1. 利用似然比检测方法，对信号是否到达进行检测

程序代码见如软件清单中的程序 p1_ML.m，其中 S 为扫频信号，实验结果如下所示：




x(t)中没有 s(t)




x(t)中包含 s(t)

```
>> p1_ML
test for x(t) = s(t)+n(t):
s(t) is detected
test for x(t) = n(t):
x(t) does not contain s(t)
```

程序检测结果

## 2. 假设 C10=2，C01=1，利用基于 Bayes 准则的检测方法，对信号是否到达进行检测

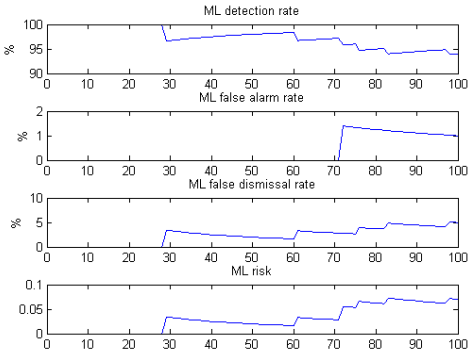
程序代码见如软件清单中的程序 p2_Bayes.m，实验结果如下所示：

```
>> p2_Bayes
test for x(t) = s(t)+n(t):
s(t) is detected
test for x(t) = n(t):
x(t) does not contain s(t)
```

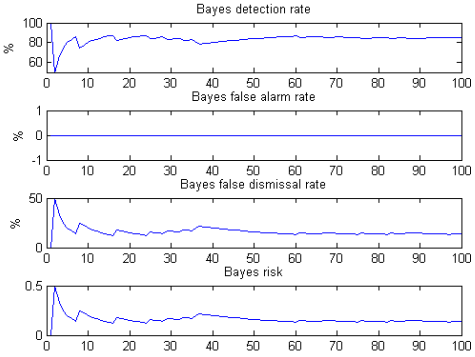
程序检测结果

## 3. 通过计算机产生的仿真数据，对两种方法的检测概率 Pd、虚警概率 Pf、漏警概率 Pm 和 Bayes 风险进行仿真计算

本题中，对 2 种方法分别取 100 个样本进行计算得到检测概率、虚警概率、漏警概率和 Bayes 风险。程序代码见如软件清单中的程序 p3_comparison.m，实验结果如下所示：




最大似然比检测，横坐标为测试数




Bayes 风险检测，横坐标为测试数

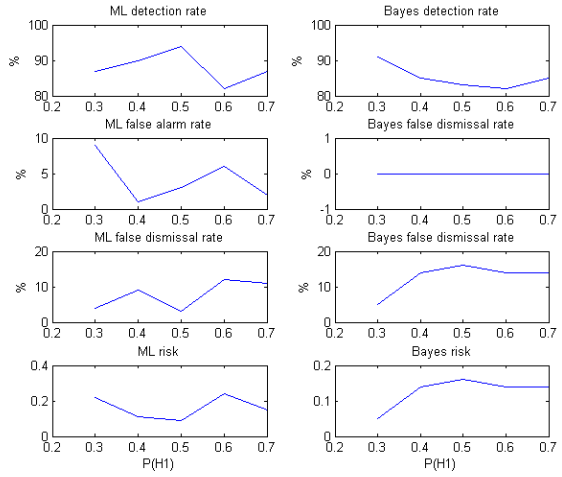
在样本数足够多时，频率收敛到概率上。下面取了最后 5 个测试展示 2 种方法对应的检测概率、虚警概率、漏警概率和 Bayes 风险。

```
test 95
ML   : detection rate:94.736842%, false alarm rate:1.052632%, false dismissal rate:4.210526%, risk:0.063158
Bayes: detection rate:85.263158%, false alarm rate:0.000000%, false dismissal rate:13.684211%, risk:0.136842
test 96
ML   : detection rate:94.791667%, false alarm rate:1.041667%, false dismissal rate:4.166667%, risk:0.062500
Bayes: detection rate:85.416667%, false alarm rate:0.000000%, false dismissal rate:13.541667%, risk:0.135417
test 97
ML   : detection rate:94.845361%, false alarm rate:1.030928%, false dismissal rate:4.123711%, risk:0.061856
Bayes: detection rate:85.567010%, false alarm rate:0.000000%, false dismissal rate:13.402062%, risk:0.134021
test 98
ML   : detection rate:93.877551%, false alarm rate:1.020408%, false dismissal rate:5.102041%, risk:0.071429
Bayes: detection rate:84.693878%, false alarm rate:0.000000%, false dismissal rate:14.285714%, risk:0.142857
test 99
ML   : detection rate:93.939394%, false alarm rate:1.010101%, false dismissal rate:5.050505%, risk:0.070707
Bayes: detection rate:84.848485%, false alarm rate:0.000000%, false dismissal rate:14.141414%, risk:0.141414
test 100
ML   : detection rate:94.000000%, false alarm rate:1.000000%, false dismissal rate:5.000000%, risk:0.070000
Bayes: detection rate:85.000000%, false alarm rate:0.000000%, false dismissal rate:14.000000%, risk:0.140000
```

100 次测试中最后 5 个测试，2 种方法的指标对比

**4. 通过改变 P(H1)和 P(H0)来改变判决的门限（风险系数 C10 和 C01 不变），观察检测方法的 Pd、Pd、Pm 和 Bayes 风险的变化；**

程序代码见如软件清单中的程序 p4_adjust_ratio.m，实验结果如下所示：



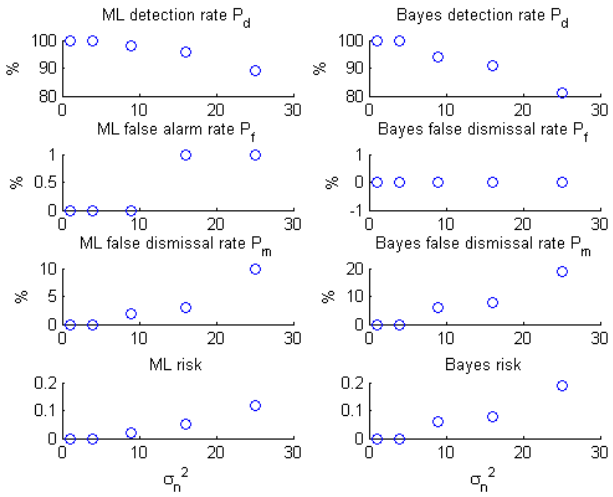

不同 P(H1)下各指标的变化（每组使用 100 个测试样例）

```
P(H1) = 0.700000, P(H0) = 0.300000
ML   : detection rate:87.000000%, false alarm rate:9.000000%, false dismissal rate:4.000000%, risk:0.220000
Bayes: detection rate:91.000000%, false alarm rate:0.000000%, false dismissal rate:5.000000%, risk:0.050000
P(H1) = 0.600000, P(H0) = 0.400000
ML   : detection rate:90.000000%, false alarm rate:1.000000%, false dismissal rate:9.000000%, risk:0.110000
Bayes: detection rate:85.000000%, false alarm rate:0.000000%, false dismissal rate:14.000000%, risk:0.140000
P(H1) = 0.500000, P(H0) = 0.500000
ML   : detection rate:94.000000%, false alarm rate:3.000000%, false dismissal rate:3.000000%, risk:0.090000
Bayes: detection rate:83.000000%, false alarm rate:0.000000%, false dismissal rate:16.000000%, risk:0.160000
P(H1) = 0.400000, P(H0) = 0.600000
ML   : detection rate:82.000000%, false alarm rate:6.000000%, false dismissal rate:12.000000%, risk:0.240000
Bayes: detection rate:82.000000%, false alarm rate:0.000000%, false dismissal rate:14.000000%, risk:0.140000
P(H1) = 0.300000, P(H0) = 0.700000
ML   : detection rate:87.000000%, false alarm rate:2.000000%, false dismissal rate:11.000000%, risk:0.150000
Bayes: detection rate:85.000000%, false alarm rate:0.000000%, false dismissal rate:14.000000%, risk:0.140000
```

不同 P(H1)下各指标的变化（每组使用 100 个测试样例）

## 5. 改变噪声的方差，观察检测方法的 Pd、Pf、Pm 和 Bayes 风险的变化

考虑到方差是以 2 次方变化的,以下采用散点图表示指标随方差不同的变化。程序代码见如软件清单中的程序 p5_adjust_variance.m，实验结果如下所示：



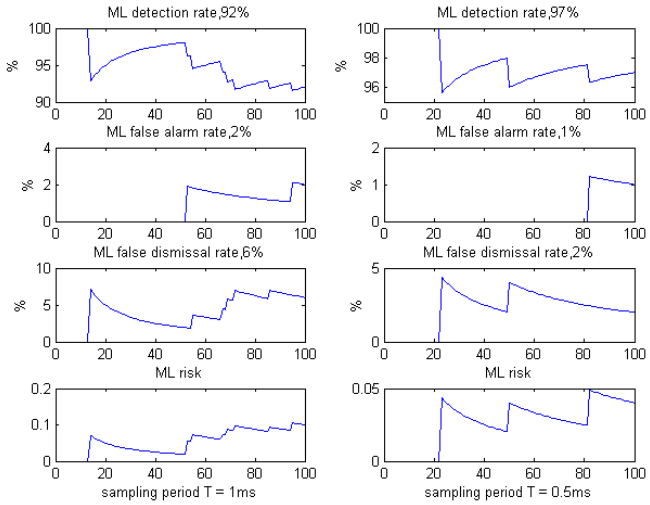

不同噪声方差下各指标的变化（每组使用 100 个测试样例）

```
n_var = 1.000000
ML   : detection rate:100.000000%, false alarm rate:0.000000%, false dismissal rate:0.000000%, risk:0.000000
Bayes: detection rate:100.000000%, false alarm rate:0.000000%, false dismissal rate:0.000000%, risk:0.000000
n_var = 4.000000
ML   : detection rate:100.000000%, false alarm rate:0.000000%, false dismissal rate:0.000000%, risk:0.000000
Bayes: detection rate:100.000000%, false alarm rate:0.000000%, false dismissal rate:0.000000%, risk:0.000000
n_var = 9.000000
ML   : detection rate:99.000000%, false alarm rate:1.000000%, false dismissal rate:0.000000%, risk:0.020000
Bayes: detection rate:98.000000%, false alarm rate:0.000000%, false dismissal rate:1.000000%, risk:0.010000
n_var = 16.000000
ML   : detection rate:95.000000%, false alarm rate:0.000000%, false dismissal rate:5.000000%, risk:0.050000
Bayes: detection rate:94.000000%, false alarm rate:0.000000%, false dismissal rate:6.000000%, risk:0.060000
n_var = 25.000000
ML   : detection rate:84.000000%, false alarm rate:2.000000%, false dismissal rate:14.000000%, risk:0.180000
Bayes: detection rate:77.000000%, false alarm rate:0.000000%, false dismissal rate:21.000000%, risk:0.210000
```

不同噪声方差下各指标的变化（每组使用 100 个测试样例）

## 6. 将信号取样间隔减小一倍(相应的取样点数增加一倍)，观察似然比检测方法的 Pd、Pf、Pm 和 Bayes 风险的变化

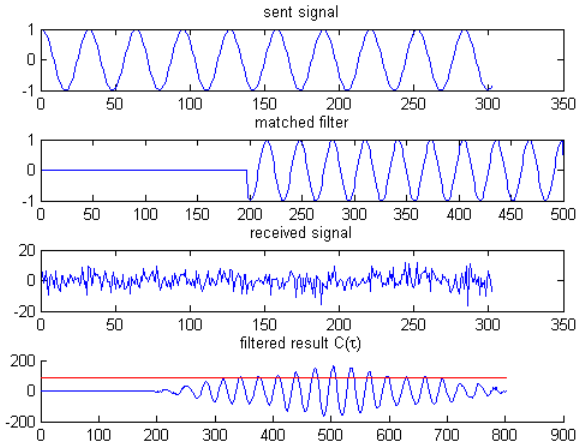
程序代码见如软件清单中的程序 p6_adjust_sampling.m，实验结果如下所示：



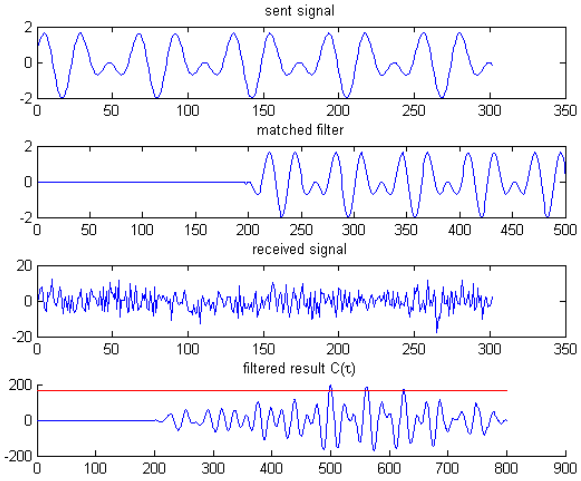

不同采样周期下各指标的对比（每组使用 100 个测试样例）

**7. 根据 s(t)设计一个离散匹配滤波器，并观察 x(n)经过该滤波器以后的输出**

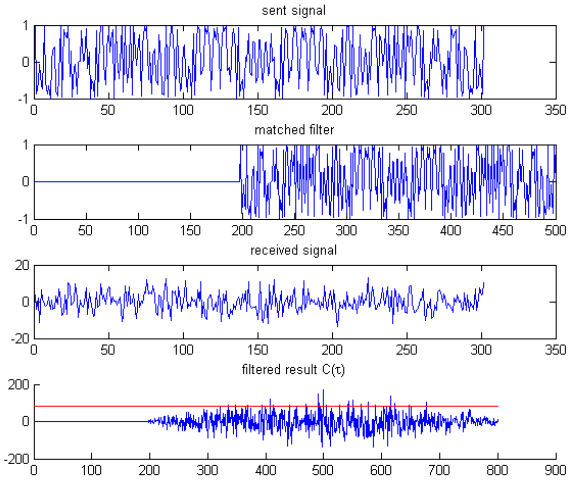
程序代码见如软件清单中的程序 p7.m，在 S 不同波形的几次测试中，S 均被检测出，实验结果如下所示：




S 为余弦信号，无延迟，红线为 G0



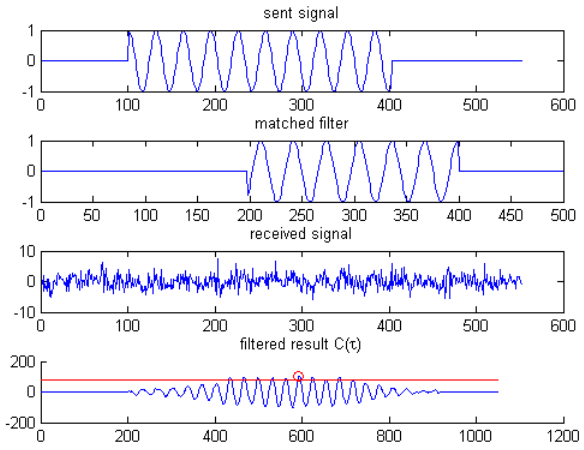

S 为弦波叠加信号，无延迟，红线为 G0




S 为扫频信号，无延迟，红线为 G0

```
>> p7
tau0 = 502.000000, C(tau0) = 136.658873, G0 = 86.352383, delay = tau0 - t0 = 2.000000
```

S 无延迟下，检测到时延接近于 0




S 为余弦信号，延迟 100ms，红线为 G0，红圈处为滤波结果的峰值

```
>> p7
tau0 = 593.000000, C(tau0) = 102.366139, G0 = 77.837616, delay = tau0 - t0 = 93.000000
```

S 延迟 100ms 下，检测到时延接近于 93ms