Stochastic Signal Processing

Experiment 3: Advance

Experimental Report 3 - Advance

- A chirp signal $X(t) = cos(2\pi(f_0 t + \frac{1}{2}kt^2))$, where $f_0 = 1000Hz$, $k = 12000\,Hz$, and the signal starts from 0 to 0.1s ($t \in [t_{min} = 0, t_{max} = 0.1]$). The frequency of chirp signal will change with time.
- Quick Question: What is the frequency now?

- Answer: it is not a point, it is an area.
    - Introductions can be found online. For example:

  https://zhuanlan.zhihu.com/p/671652386

Experimental Report 3 - Advance

知乎 首发于 雷达学习 切换模式

Chirp信号（特殊的调频信号）

FightingChiken
圣文字B：世界调和（The Balance）

27 人赞同了该文章

收起

号（特殊的调频信号）

Chirp信号（特殊的调频信号）

想理解这玩意得先理解调频：基于matlab试验的对调频终极理解 - 知乎 (zhihu.com)

对这里面的参数进行解释

瞬时频率：$f(t)$

c为瞬时$chirp$度(斜率)

f_1：终止频率

f_0：扫频起始频率T：扫频周期

这是一般的做法，即限定频率的上下限，然后依据信号的持续时间，去定义k

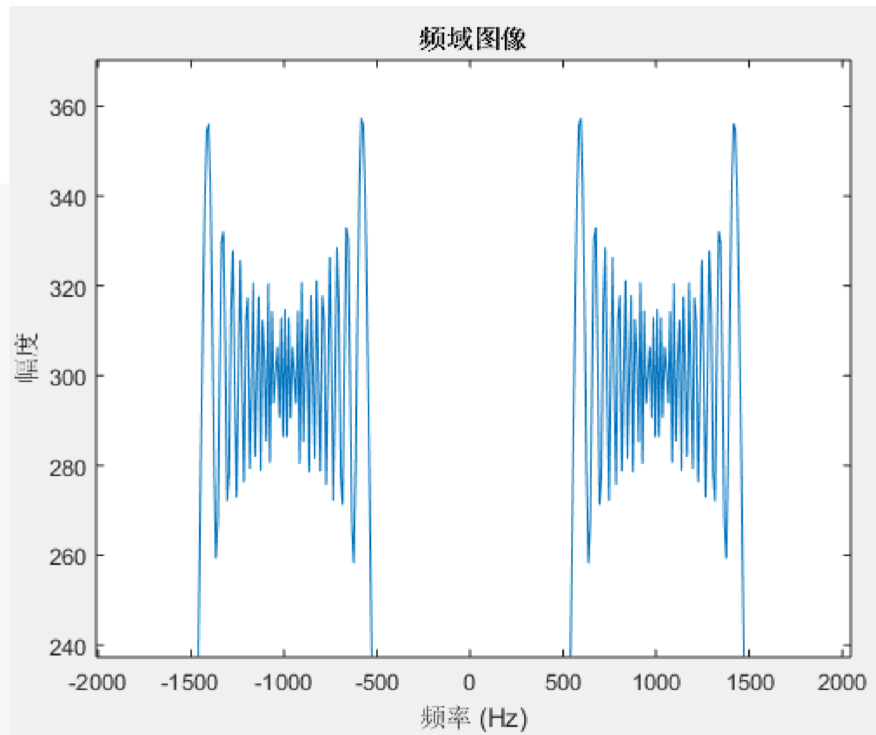
实验部分

时域和频域分析

```
% 参数设置
A = 4;
phi_0 = 0;
f_0 = 500;
f_end = 1500;
T_period = 0.1;

% 采样参数
Fs = 15000; % 采样频率
T = 1/Fs;   % 采样周期
t = 0:T:T_period-T; % 从0到周期进行采样

% 生成信号
c = (f_end - f_0) / T_period; % 计算线性调频斜率
x_t = A * cos(phi_0 + 2 * pi * (f_0 * t + 0.5 * c * t.^2));
```



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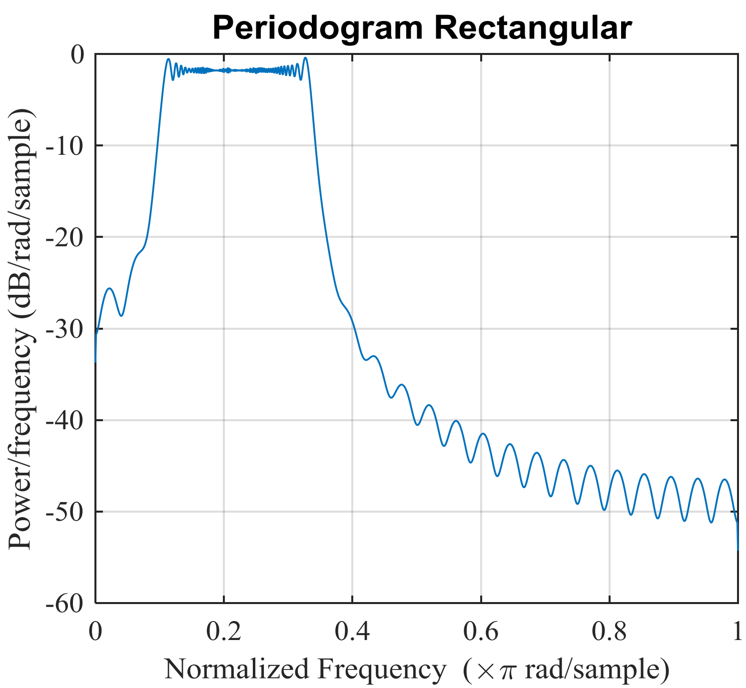
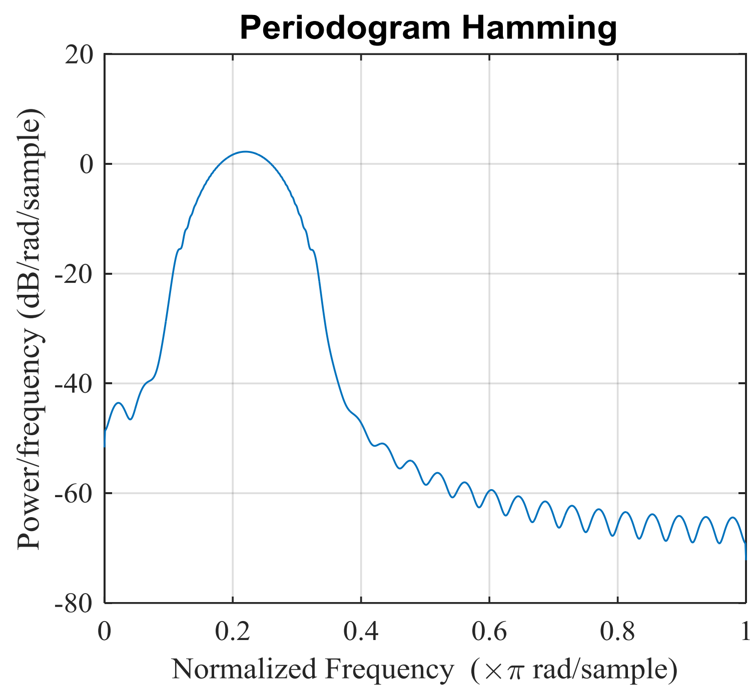
- A chirp signal $X(t) = cos(2\pi(f_0 t + \frac{1}{2}kt^2))$, where $f_0 = 1000Hz$, $k = 12000\ Hz$, and the signal starts from 0 to 0.1s ($t \in [t_{min} = 0, t_{max} = 0.1]$). The frequency of chirp signal will change with time.
- We use the periodogram to see the power spectrum:

```
fs = 20000; % sample rate
f0 = 1000; %
% kf0 = 12000;
% kf0 = 20000;
T_end=0.1;
kf0 = 2000;
T_end=1;
T=1/fs;
t = 0:T:T_end-T; %  sample point
x = sin(2*pi*(t.*f0+kf0.*t.^2));
% x = sin(2*pi*t.*(f0+kf0.*t)) + 0.1*randn(size(t));
subplot(1,2,1)
periodogram(x,rectwin(length(x))); % Periodogram with rectangular Window
set(gca,'fontsize',12,'fontname','times');
title('\fontname{} Periodogram Rectangular','fontsize',14);
subplot(1,2,2)
periodogram(x,hamming(length(x))); % Periodogram with Hamming Window
set(gca,'fontsize',12,'fontname','times');
title('\fontname{} Periodogram Hamming','fontsize',14);
set(gcf,'Units','centimeter','Position',[10 10 28 10]);
```

Experimental Report 3 - Advance

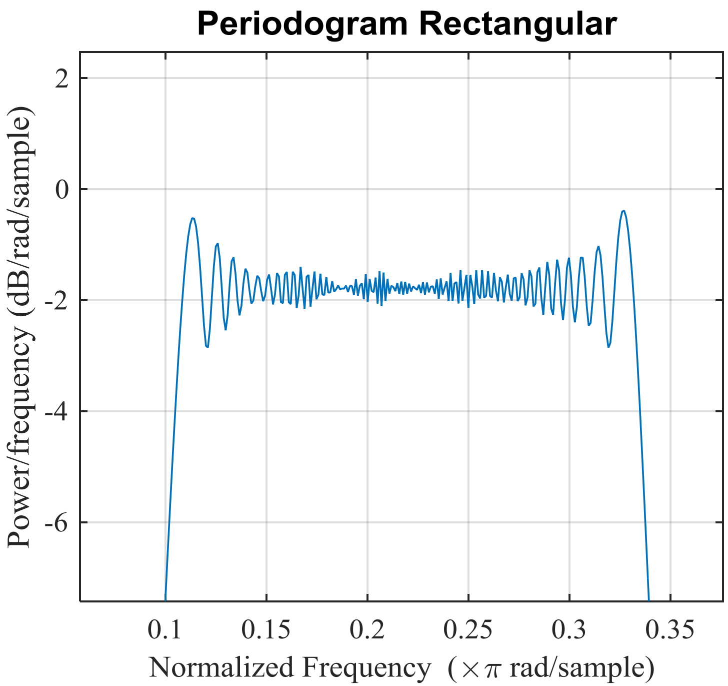
- $t \in [t_{min} = 0, t_{max} = 0.1]), k = 12000\ Hz$

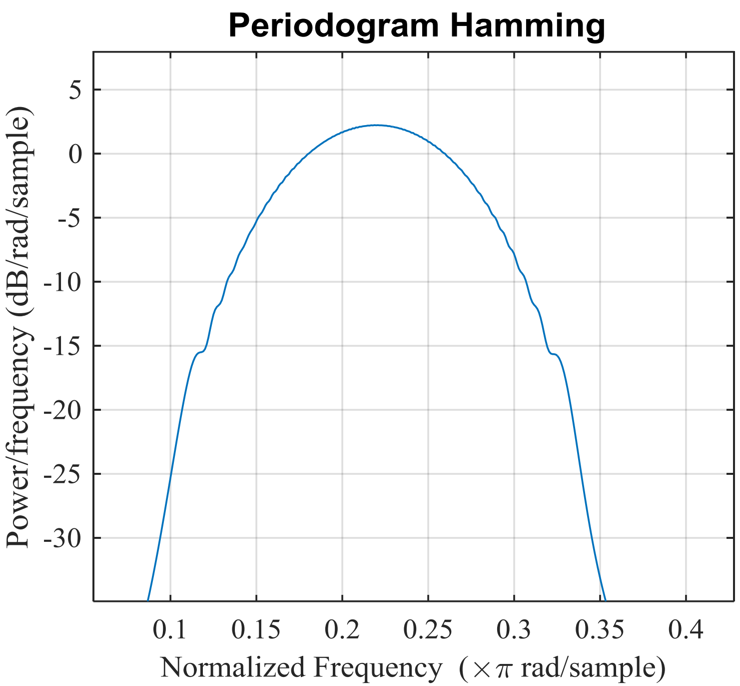




Experimental Report 3 - Advance

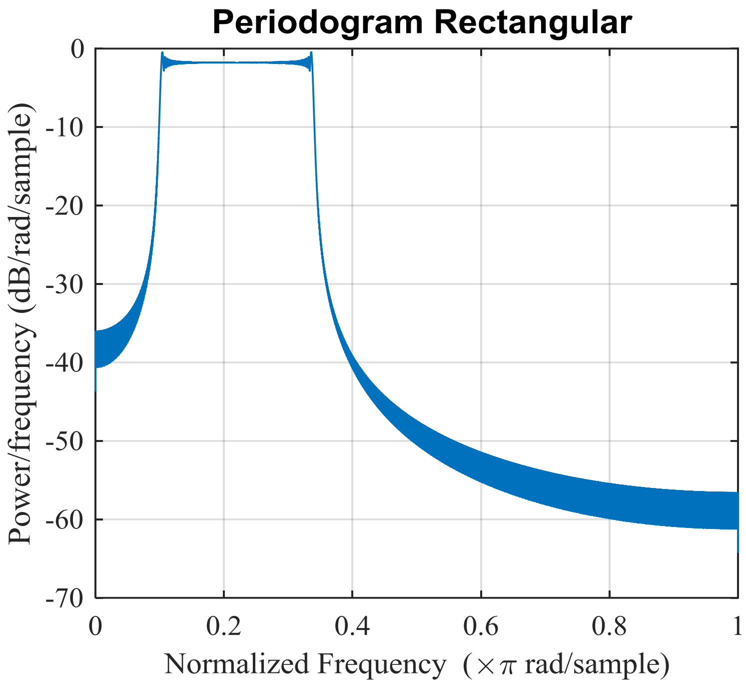
- $t \in [t_{min} = 0, t_{max} = 0.1]), k = 12000\ Hz$

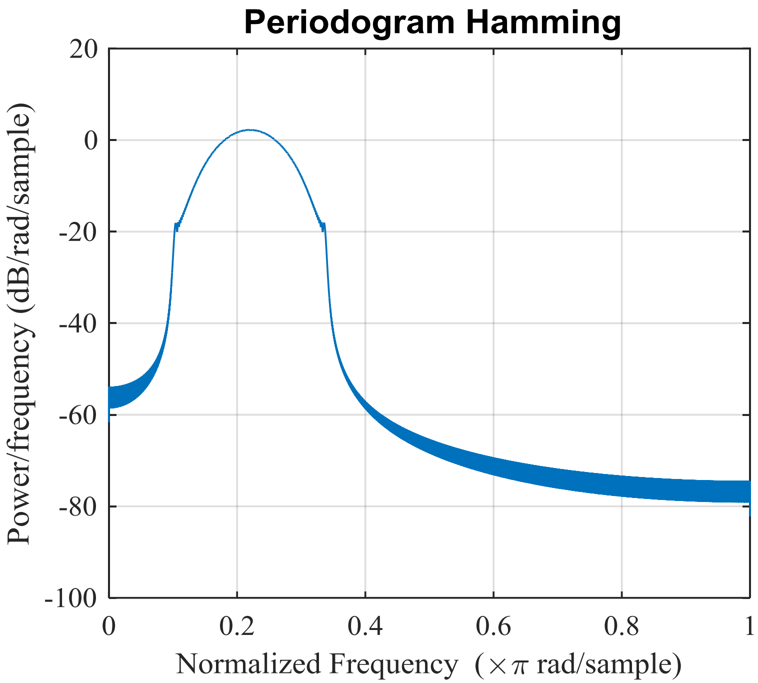




Experimental Report 3 - Advance

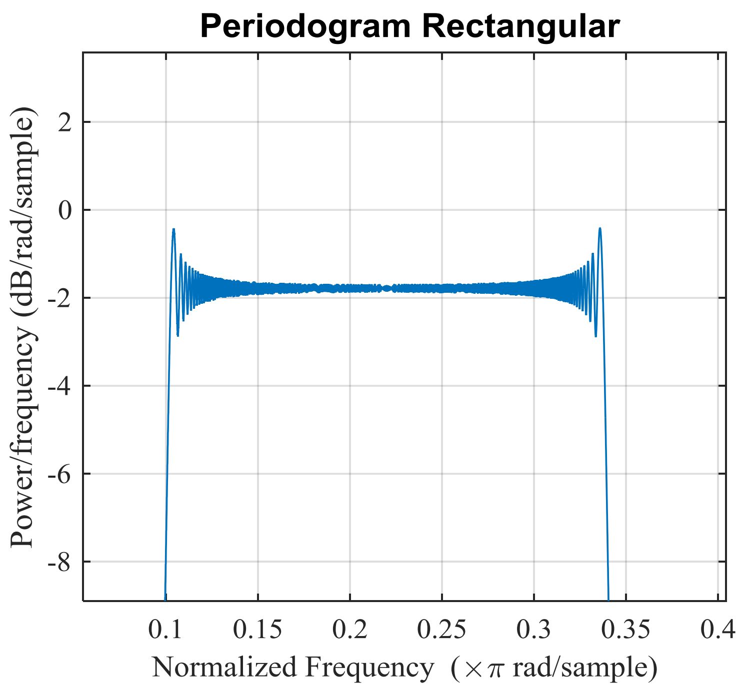
- $t \in [t_{min} = 0, t_{max} = 1]), k = 1200\ Hz$

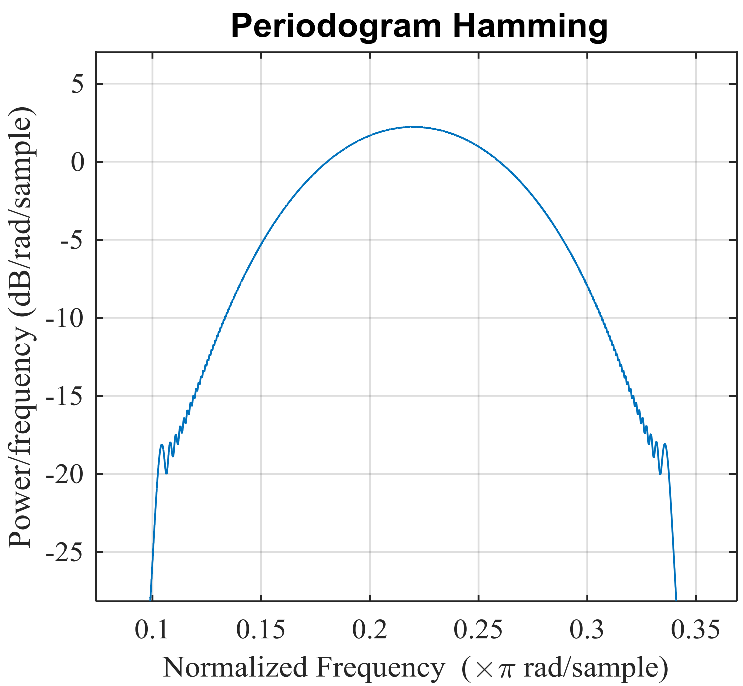


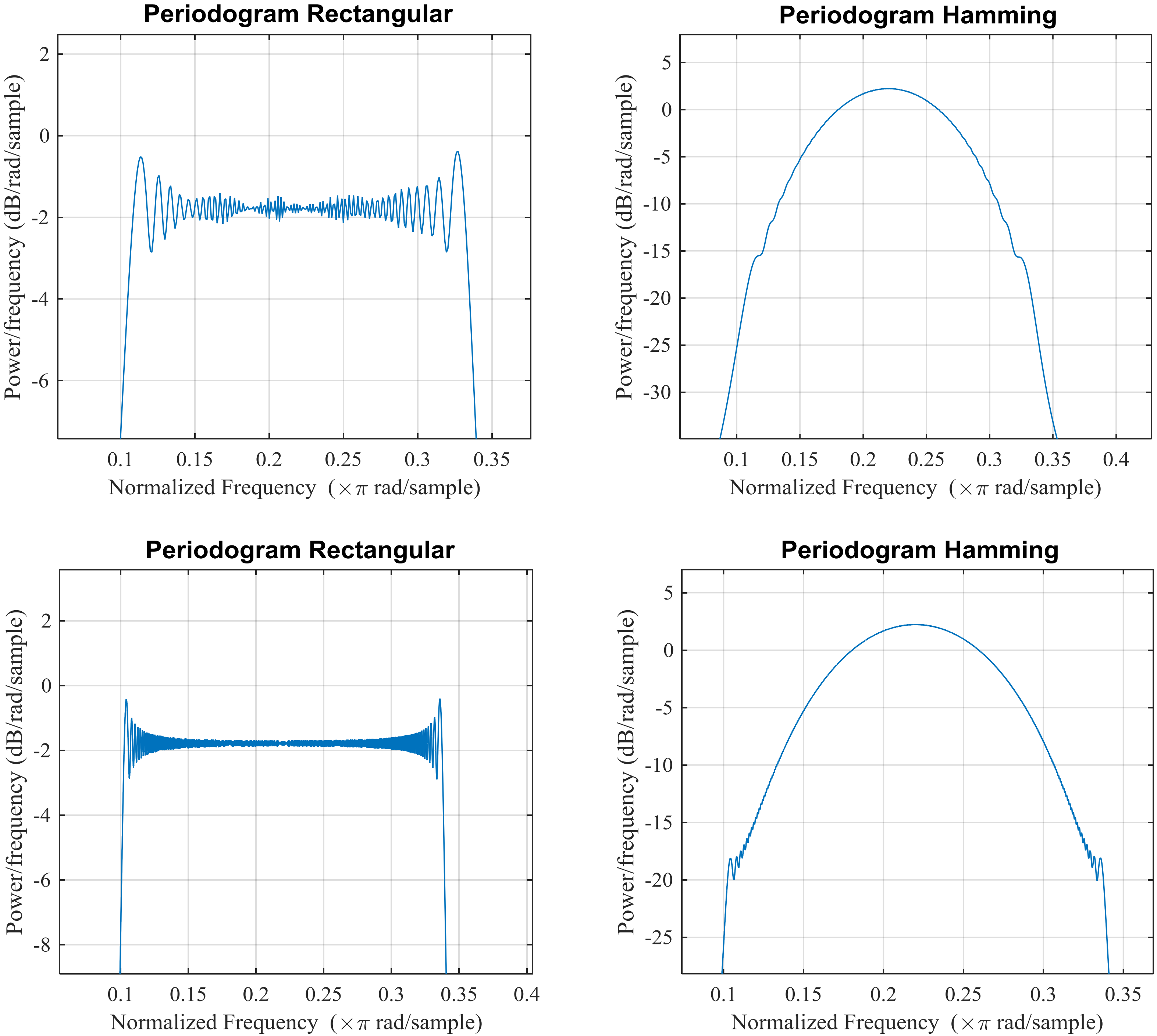


Experimental Report 3 - Advance

- $t \in [t_{min} = 0, t_{max} = 1]), k = 1200\ Hz$






Periodogram Rectangular
Power/frequency (dB/rad/sample)
Normalized Frequency (×π rad/sample)
Periodogram Hamming
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Experimental Report 3 - Advance (40 points)

A chirp signal $X(t) = cos(2\pi(f_0 t + \frac{1}{2}kt^2))$, where $f_0 = 1000Hz,\ k = 12000\ Hz$, and the signal starts from 0 to 0.1s ($t \in [t_{min} = 0, t_{max} = 0.1]$). The frequency of chirp signal will change with time. Here we use a sampling frequency 50000Hz.

The chirp signal is sent out by a radar, and reflected by a target. We ignore any attenuation here, and assume that we receive a signal $Y(t) = X_1(t) + N(t)$, where $X_1(t)$ is a shift of $X(t)$. The duration of $X_1(t)$ is also 0.1s, but the end point is located between 0.11s and 1s in receiving system, or says, following a uniform distribution between [0.11, 1]. (in many radar, a ultra close target cannot be detected)

You are required to:

Experimental Report 3 - Advance (40 points)

1) Design a matched filter for chirp signal in Matlab. Use this matched filter to estimate the end time of this signal; and test it under different signal-to-noise ratios (SNR = $10 * log_{10}(P_s/\sigma^2)$ dB), where P_s is the average power spectrum. SNR should be designed by yourself. Finally, calculate the MSE and success rate of this system. (25 points)

Formula Definition

a. MSE = $\frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{N}(t_e - t_r)^2$, t_e is estimated time, t_r is true time

b. Success rate P =K/N, when $|t_e - t_r|$<0.03s, it is successful, otherwise, it is failed. K represent the number of successes.

N is the number of tests (independent runs), you can use $\mathrm{N} \geq 500$.

Experimental Report 3 - Advance (40 points)

1) Design a matched filter for chirp signal in Matlab. Use this matched filter to estimate the end time of this signal; and test it under different signal-to-noise ratios (SNR = $10 * log_{10}(P_s/\sigma^2)$ dB), where P_s is the average power spectrum. SNR should be designed by yourself. And, calculate the MSE and success rate under different SNR. (25 points)

Requirement:

1. Please plot your system flow chart in your report.
2. Give your MSE and success rate results, and analysis, under different SNR. (Hint: use table or figure, and you should choose an SNR range that can at least see '100% success' and '100% fail')

You are required to submit your code, and your code should directly give all the tables or figures in your report.

Experimental Report 3 - Advance (40 points)

2) Note that 1) is based on the ‘match filter’. Now, assume that you did not send out any signal, but a target sent out such a signal. And, you do not know what signal the target sent, but you know that the duration is 0.1s. The end time of the signal is still in [0.11, 1]. Please use the periodogram (can use the Matlab default one or yours) to detect the end time of the signal, test it under different signal-to-noise ratios, and calculate the MSE and success rate of this new method. (15 points)

Hint:

1) if the signal is in [0.35,0.45], and what will happen if you do periodogram on time [0.3,0.4]? [0.35,0.45]? [0.6,0.7]?
2) How to improve the accuracy?

Experimental Report 3 - Advance (40 points)

2) Note that 1) is based on the 'match filter'. Now, assume that you did not send out any signal, but a target sent out such a signal. And, you do not know what signal the target sent, but you know that the duration is 0.1s. The end time of the signal is still in [0.11, 1]. Please use the periodogram (can use the Matlab default one or yours) to detect the end time of the signal, and calculate the MSE and success rate of this **new method** under different SNR. (15 points)

Requirement:

1. Please plot your algorithm flow chart in your report.
2. Give your MSE and success rate results, and analysis, under different SNR, and compare the results with 1). (Hint: use table or figure, and you should choose an SNR range that can at least see '100% success' and '100% fail')

You are required to submit your code, and your code should directly give all the tables or figures in your report.