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Principles of Communication Systems: Homework 2

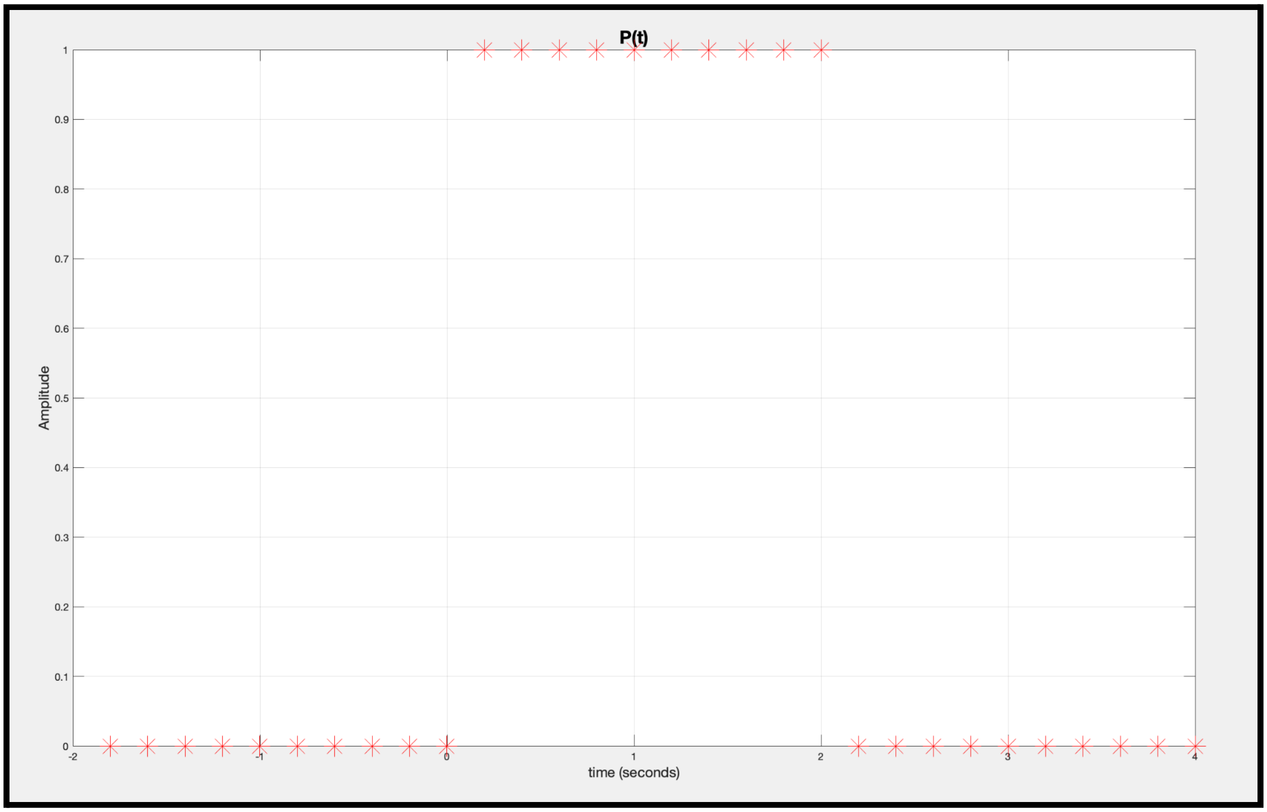
Theory

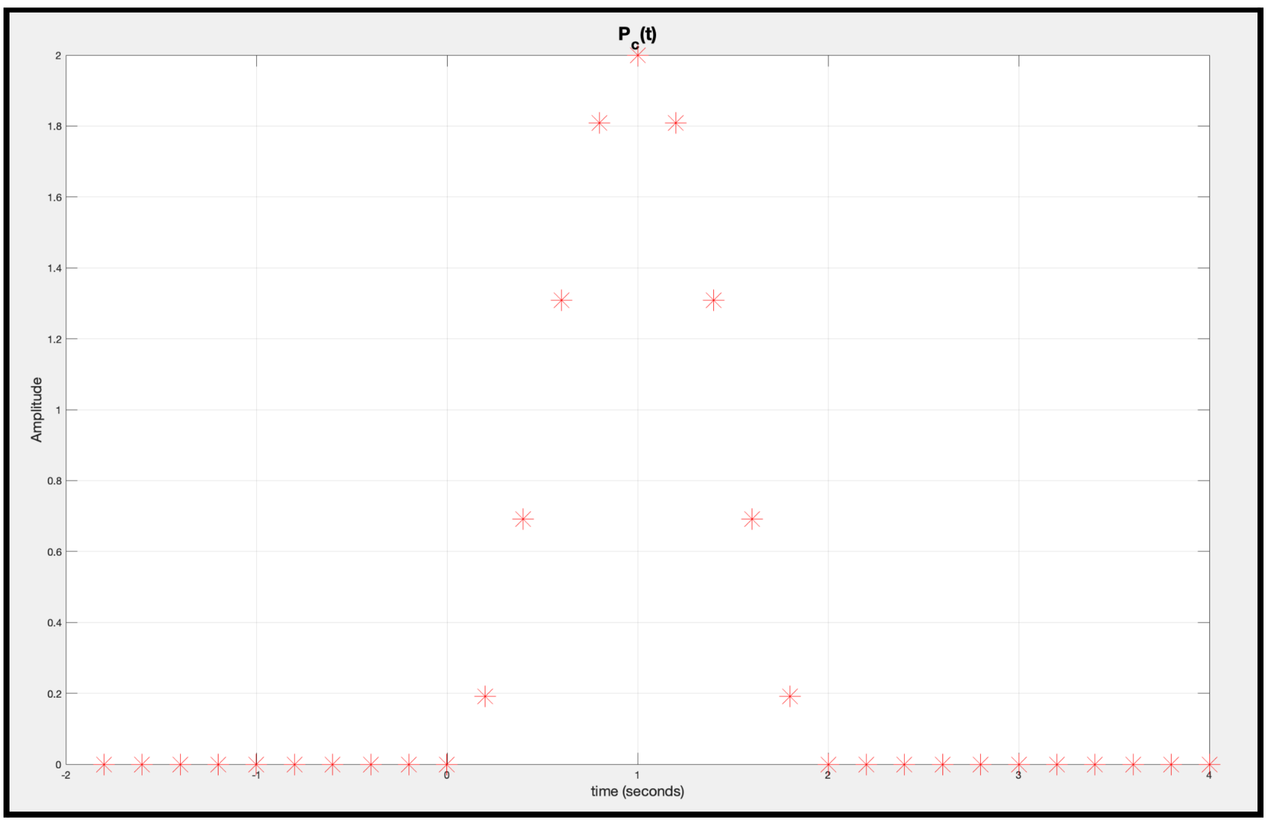
We take a random seed and generate 1000 random bits. Of those 1000 random bits, we take the first 10 and generate a signal that has 10 samples per 2 seconds and is shaped into two different pulses. P(t) which is a square signal, and $P_C(t)$ which is a cosine shaped pulse. We translate the first 10 bits into these pulses and specifically 1 → 1 and 0 → -1, where -1 is the flipped version of P(t) and $P_C(t)$. The resulting signals are S(t) and $S_C(t)$.

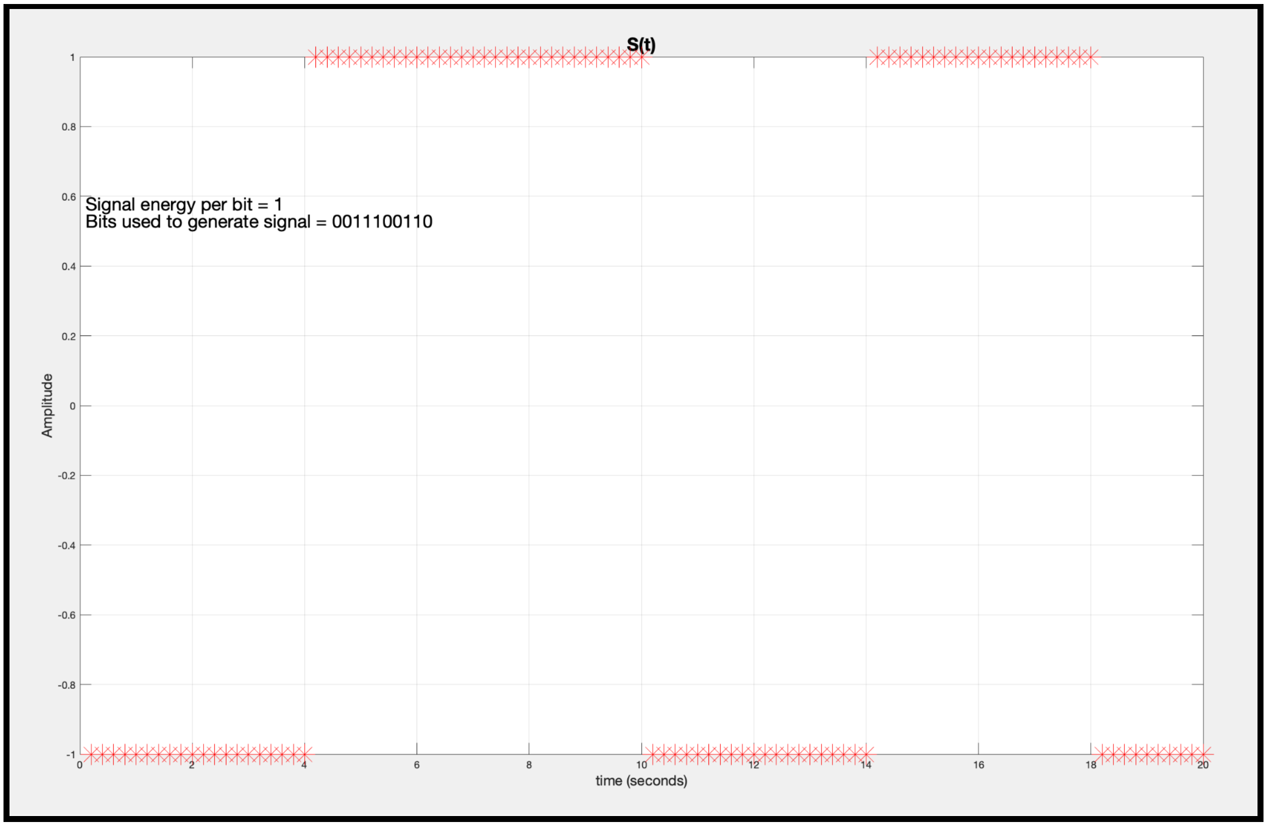
We then find the fourier transform of the signal and create S(f) and $S_C(f)$, and plot these out. The idea is that of all the four generated signals we can find the energy of each signal (per bit), and find specific bandwidths of the same signals such as the 90% bandwidth and the 3dB bandwidth. Here we use the discrete time signals to find energy with the formula:

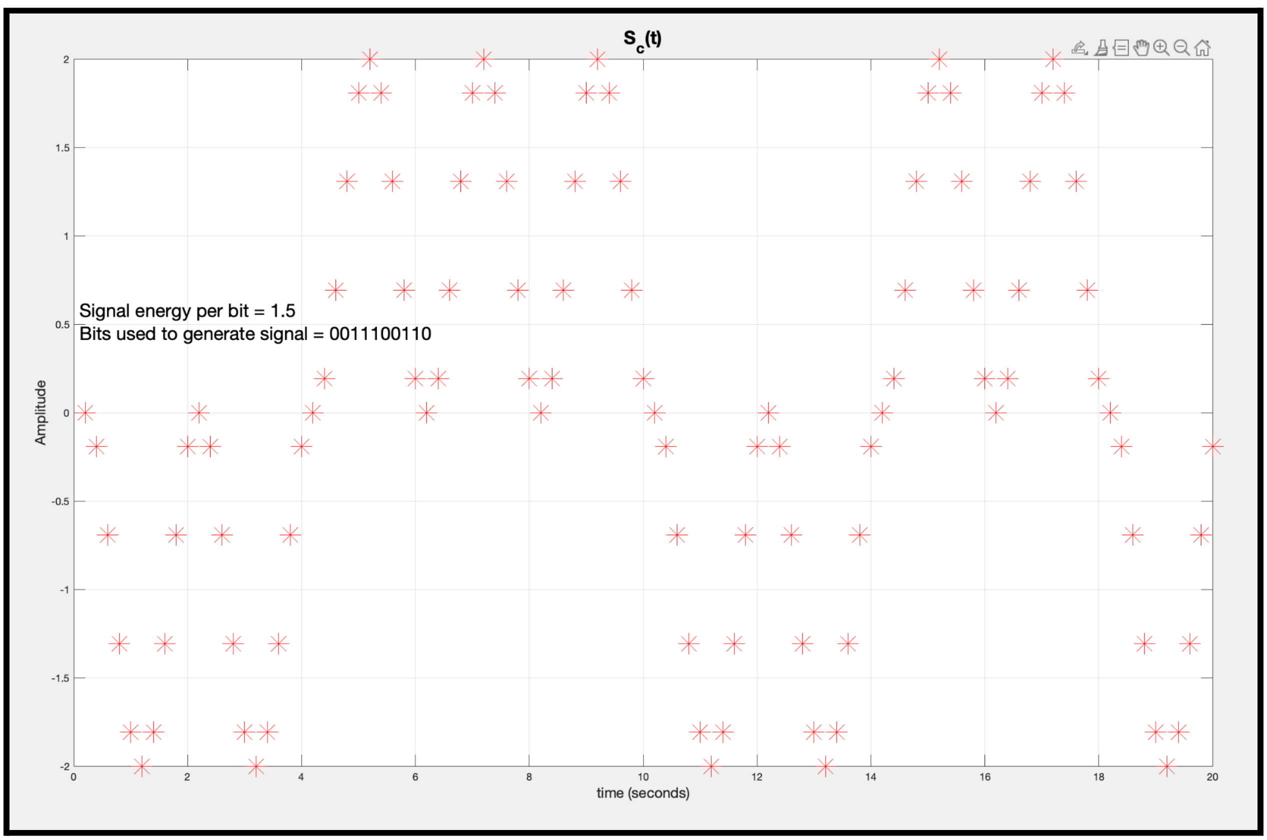
$$(\sum_{-\infty}^{\infty} x[n]^2))/N\ samples.$$

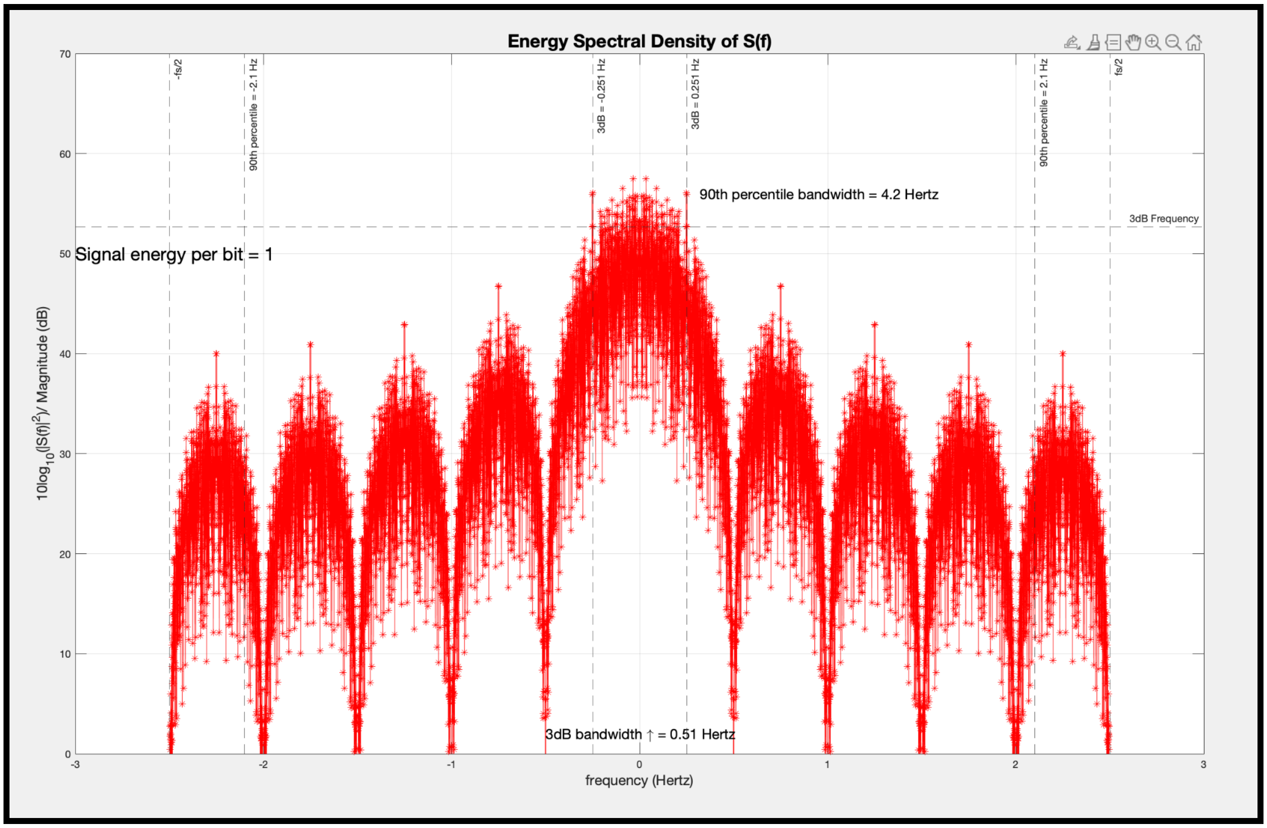
Results


P(t)
Amplitude
time (seconds)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
-2
-1
0
1
2
3
4

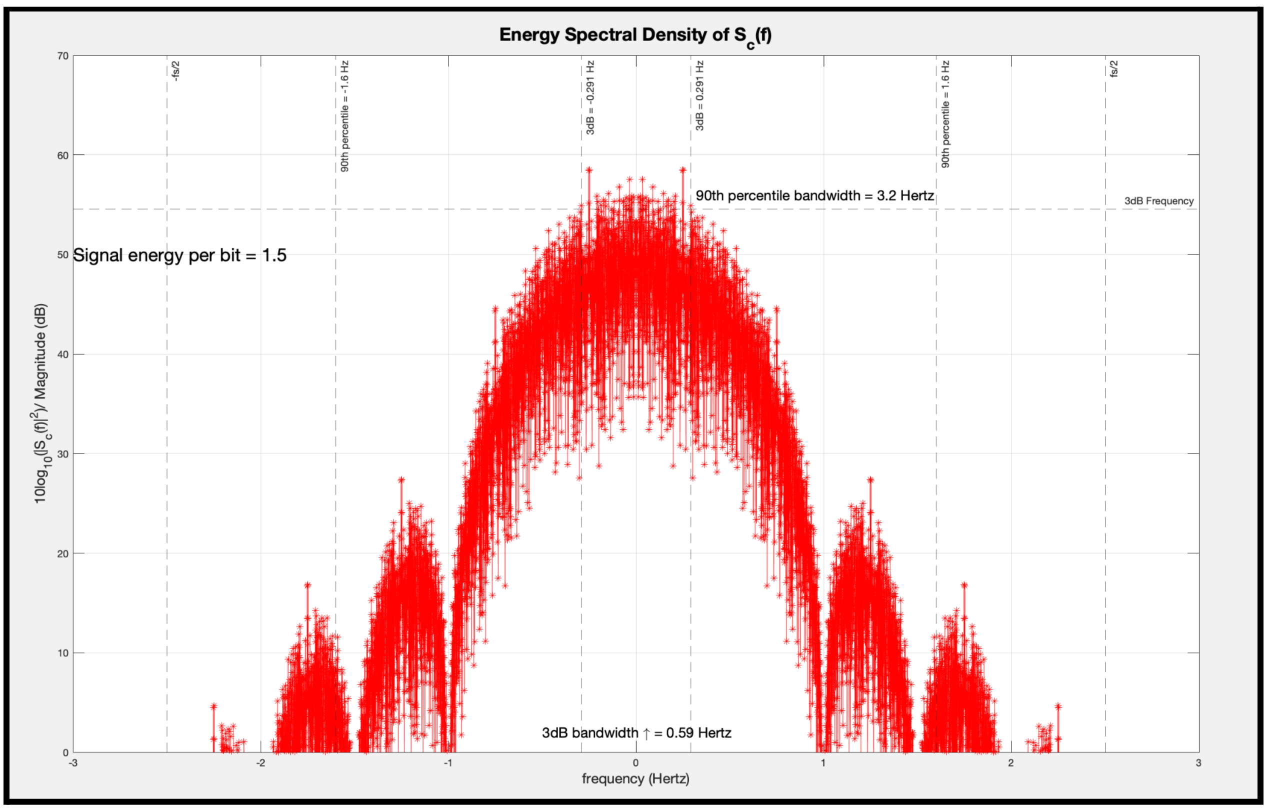

$P_c(t)$
Amplitude
time (seconds)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
-2
-1
0
1
2
3
4


S(t)
Signal energy per bit = 1
Bits used to generate signal = 0011100110
Amplitude
time (seconds)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
2
4
6
8
10
12
14
16
18
20


$S_c(t)$
Signal energy per bit = 1.5
Bits used to generate signal = 0011100110
Amplitude
time (seconds)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
2
4
6
8
10
12
14
16
18
20



Energy Spectral Density of S(f)
-fs/2
90th percentile = -2.1 Hz
3dB = -0.251 Hz
3dB = 0.251 Hz
90th percentile = 2.1 Hz
fs/2
90th percentile bandwidth = 4.2 Hertz
3dB Frequency
Signal energy per bit = 1
3dB bandwidth ↑ = 0.51 Hertz
10log10(|S(f)|2)/ Magnitude (dB)
frequency (Hertz)



Energy Spectral Density of Sc(f)
-fs/2
90th percentile = -1.6 Hz
3dB = -0.291 Hz
3dB = 0.291 Hz
90th percentile = 1.6 Hz
fs/2
90th percentile bandwidth = 3.2 Hertz
3dB Frequency
Signal energy per bit = 1.5
3dB bandwidth ↑ = 0.59 Hertz
10log10(|Sc(f)|2)/ Magnitude (dB)
frequency (Hertz)

MATLAB CODE

```
rng(193004150);
bb = randi([0 1], 1, 1000);
st = zeros(1,10000);
j = 1;
Ts = 0.2;
tt = (1:10000)*Ts;

pc = [0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0];
ft=[-9:20]*Ts;
figure(1);
plot(ft, pc, 'r*', 'markersize',20);
grid on;
title('P(t)', 'fontsize', 18);
ylabel('Amplitude', 'fontsize', 14);
xlabel('time (seconds)', 'fontsize', 14);

pct = [0 0 0 0 0 0 0 0 0 0 0.191 0.691 1.309 1.809 2 1.809 1.309 0.691 0.191 0 0 0 0 0 0 0 0 0 0 0];
ft=[-9:20]*Ts;
figure(2);
plot(ft, pct, 'r*', 'markersize',20);
grid on;
title('P_c(t)', 'fontsize', 18);
ylabel('Amplitude', 'fontsize', 14);
xlabel('time (seconds)', 'fontsize', 14);


for i=1:length(bb)
   if  bb(i) == 0
      st(j) = -1;
      st(j+1) = -1;
      st(j+2) = -1;
      st(j+3) = -1;
      st(j+4) = -1;
      st(j+5) = -1;
      st(j+6) = -1;
      st(j+7) = -1;
      st(j+8) = -1;
      st(j+9) = -1;
      j = j+10;
   else
      st(j) = 1;
      st(j+1) = 1;
      st(j+2) = 1;
      st(j+3) = 1;
      st(j+4) = 1;
      st(j+5) = 1;
      st(j+6) = 1;
      st(j+7) = 1;
      st(j+8) = 1;
      st(j+9) = 1;
      j = j+10;
   end
end

% energy per bit
psum=0;
for i=1:10
   psum = psum + st(i)^2;
end
psum = psum/(10);

figure(3);
```

```
plot(tt, st, 'r*', 'markersize', 20)
title('S(t)', 'fontsize', 18);
ylabel('Amplitude', 'fontsize', 14);
xlabel('time (seconds)', 'fontsize', 14);
text(0.1,0.58,'Signal energy per bit = 1', 'fontsize', 18)
text(0.1,0.53,'Bits used to generate signal = 0011100110', 'fontsize', 18)
grid on;
xlim([0 20]);


sct = zeros(1,10000);
j = 1;
for i=1:length(bb)
    if  bb(i) == 1
        sct(j) = 0;
        sct(j+1) = 0.191;
        sct(j+2) = 0.691;
        sct(j+3) = 1.309;
        sct(j+4) = 1.809;
        sct(j+5) = 2;
        sct(j+6) = 1.809;
        sct(j+7) = 1.309;
        sct(j+8) = 0.691;
        sct(j+9) = 0.191;
        j = j+10;
    else
        sct(j) = 0;
        sct(j+1) = -0.191;
        sct(j+2) = -0.691;
        sct(j+3) = -1.309;
        sct(j+4) = -1.809;
        sct(j+5) = -2;
        sct(j+6) = -1.809;
        sct(j+7) = -1.309;
        sct(j+8) = -0.691;
        sct(j+9) = -0.191;
        j = j+10;
    end
end

% energy per bit
esum=0;
for i=1:10
    esum = esum + sct(i)^2;
end
esum = esum/(10);


figure(4);
plot(tt, sct, 'r*', 'markersize', 20)
title('S_c(t)', 'fontsize', 18);
ylabel('Amplitude', 'fontsize', 14);
xlabel('time (seconds)', 'fontsize', 14);
text(0.1,0.58,'Signal energy per bit = 1.5', 'fontsize', 18)
text(0.1,0.45,'Bits used to generate signal = 0011100110', 'fontsize', 18)
grid on;
xlim([0 20]);


Fs = 1/Ts;

figure(5);
ftst = fft(st);
SF = 10*log10(abs(fftshift(ftst)).^2);
freq = -Fs/2:Fs/length(sct):Fs/2-(Fs/length(sct));
```

```matlab
plot(freq, SF, 'r*-');
grid on;
title('Energy Spectral Density of S(f)', 'fontsize', 18);
ylabel('10log_1_0(|S(f)|^{2})/ Magnitude (dB)', 'fontsize', 14);
xlabel('frequency (Hertz)', 'fontsize', 14);
ylim([0 70]);
xlim([-3 3]);
xline(-2.5, '--', '-fs/2');
xline(2.5, '--', 'fs/2');
yline(52.7, '--', '3dB Frequency');
xline(-0.25, '--', '3dB = -0.251 Hz');
xline(0.25, '--', '3dB = 0.251 Hz');
text(-3,50,'Signal energy per bit = 1', 'fontsize', 18)
text(-0.5,2,'3dB bandwidth \uparrow = 0.51 Hertz', 'fontsize', 14)
xline(-2.1, '--', '90th percentile = -2.1 Hz');
xline(2.1, '--', '90th percentile = 2.1 Hz');
text(0.32,56,'90th percentile bandwidth = 4.2 Hertz', 'fontsize', 14)

figure(6);
ftsct = fft(sct);
SFC = 10*log10(abs(fftshift(ftsct)).^2);
freq = (-Fs/2):Fs/length(sct):(Fs/2)-(Fs/length(sct));
plot(freq, SFC, 'r*-');
grid on;
title('Energy Spectral Density of S_c(f)', 'fontsize', 18);
ylabel('10log_1_0(|S_c(f)|^{2})/ Magnitude (dB)', 'fontsize', 14);
xlabel('frequency (Hertz)', 'fontsize', 14);
ylim([0 70]);
xlim([-3 3]);
yline(54.53, '--', '3dB Frequency');
xline(-2.5, '--', '-fs/2');
xline(2.5, '--', 'fs/2');
xline(-0.2905, '--', '3dB = -0.291 Hz');
xline(0.2905, '--', '3dB = 0.291 Hz');
text(-3,50,'Signal energy per bit = 1.5', 'fontsize', 18)
text(-0.5,2,'3dB bandwidth \uparrow = 0.59 Hertz', 'fontsize', 14)
xline(-1.6, '--', '90th percentile = -1.6 Hz');
xline(1.6, '--', '90th percentile = 1.6 Hz');
text(0.32,56,'90th percentile bandwidth = 3.2 Hertz', 'fontsize', 14)

% S(f) and S_c(f) signal energy per bit
sdsum=0;
for i=1:length(SFC)
  sdsum = sdsum + (SFC(i)^2);
end
sdsum = sdsum/10000;


sfsum=0;
for i=1:length(SFC)
  sfsum = sfsum + (SFC(i)^2);
end
sfsum = sfsum/10000;
```