Problem 1.

(a)

$$s(t) = \sum_n s(nT_s)\text{sinc}\left(\frac{t - nT_s}{T_s}\right) = \sum_n s_1[n]\text{sinc}\left(\frac{t - nT_s}{T_s}\right)$$

Since sinc functions represent an orthogonal basis, with squared norm T_s,

$$\|s(t)\|^2 = \sum_n s_1^2[n]T_s = T_s\|s_1[n]\|^2$$

and, similarly,

$$\|s(t)\|^2 = \sum_n s_2^2[n]\frac{T_s}{2} = \frac{T_s}{2}\|s_2[n]\|^2$$

Or, intuitively,

$$\|s_1[n]\|^2 = \sum_{n=0}^{N-1} s^2(nT_s)$$

$$\|s_2[n]\|^2 = \sum_{n=0}^{2N-1} s^2(nT_s/2) = \sum_{k=0}^{N-1} s^2(kT_s) + \sum_{k=0}^{N-1} s^2(kT_s + T_s/2) \approx 2\sum_{n=0}^{N-1} s^2(nT_s) = 2\|s_1[n]\|^2$$

Since T_s is small enough, $s(kT_s) \approx s(kT_s + T_s/2)$.

$$\|s(t)\|^2 = \int_0^{T_p} s^2(t) = \sum_{n=0}^{N-1} \int_{nT_s}^{(n+1)T_s} s^2(t)\mathrm{d}t \approx \sum_{n=0}^{N-1} s^2(nT_s)T_s = T_s\|s_1[n]\|^2$$

(b) `result=map_4qam(source+1);`

(c) The overall frequency range is $F_s = 400$ Hz. Because of the use of `fftshift`, the graph will be centered on 0 Hz.

The bandwidth of the signal (edge-to-edge) is $F_s * 600/800 = 300$ Hz.

The minimum sampling frequency is 300 Hz.

Problem 2.

(a) Only choose the first 250+10-1 bits for the correlation. This way you know that the maximum that you find corresponds to the first frame. Then remove the ramp-up part from the correlation.

```
N=250;
P=10;
bits_short=bits_new(1:N+P-1);
%compute the correlation between bits and preamble
c=xcorr(bits_short, preamble_new);

%remove ramp-up
c=c(length(bits_short):end)

%find the maximum value
[max_c, pos]=max(c);  %do not use abs, since [0000011111] will also give a maximu

%pos is the position where the first frame starts
```

Or

Since the bits are noise-free, each maximum will have the same value (10). The start of the first frame will correspond to the first found maximum.

```
%compute the correlation between bits and preamble
c=xcorr(bits_new, preamble_new);

%remove ramp-up
c=c(length(bits_new):end)

%find the maximum value
[max_c, pos]=max(c);  %do not use abs, since [0000011111] will also give a maximu
```