IIR FILTERS (INFINITE IMPULSE RESPONSE FILTERS)

- IIR filters are implemented using the recursion

The General IIR Filter

- The general form for the IIR filter is:

$$y(n) = \sum_{k=0}^{N} a_k x(n-k) - \sum_{j=1}^{M} b_j y(n-j)$$

$$= a_0 x(n) + a_1 x(n-1) + a_2 x(n-2) + \ldots + a_N x(n-N)$$

$$- b_1 y(n-1) - b_2 y(n-2) - \ldots - b_M y(n-M)$$

Recursion

$$y_n = x_n + y_n - 1$$

$$y_0 = x_0 + y_{-1}$$

$$y_1 = x_1 + y_0$$

$$y_2 = x_2 + y_1$$

... and so on.

$$Y10 = x10 + y9$$

$$Y10 = x10 + x9 + x8 + x7 + x6 + x5 + x4 + x3 + x2 + x1 + x0$$

Advantages and disvantages IIR

- Advantages of recursive filter
  - Generally require a much lower order filter, they are faster than FIR filters
- Disadvantages
  - The feedback component will also feed back the noise from the original signal.

Some IIR Filter

- Chebyshev
- Butterworth

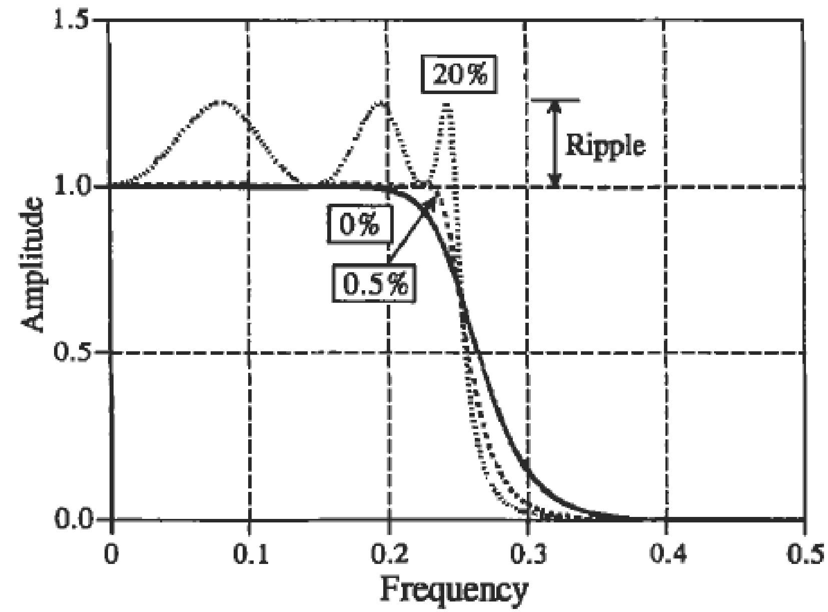
CHEBYSHEV FILTER

Chebyshev filters

- Are analog and digital filters that use a mathematical strategy for achieving a faster roll off by allowing ripple in the frequency response (they use Chebyshev polynomials).

Ripple vs. Roll-off

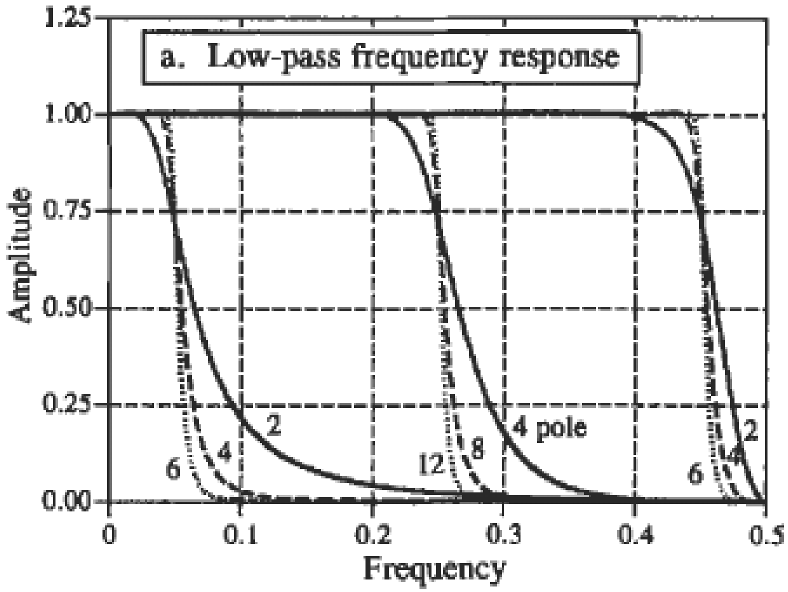
FIGURE 20-1
The Chebyshev response. Chebyshev filters achieve a faster roll-off by allowing ripple in the passband. When the ripple is set to 0%, it is called a *maximally flat* or *Butterworth* filter. Consider using a ripple of 0.5% in your designs; this passband unflatness is so small that it cannot be seen in this graph, but the roll-off is much faster than the Butterworth.

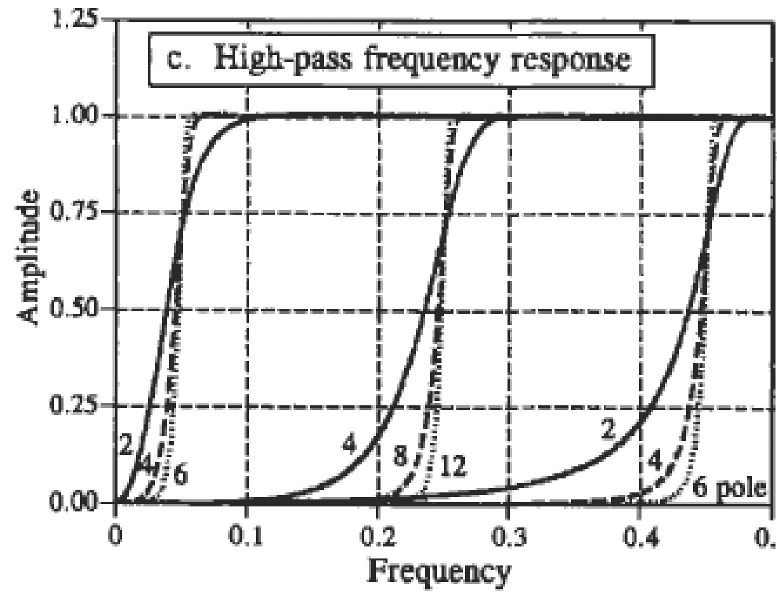


A ripple of 0.5% is often a good choice for digital filters.

Chebyshev filter design

- High-pass or low-pass response
- Cutoff frequency
- The percent ripple in the passband
- Number of poles

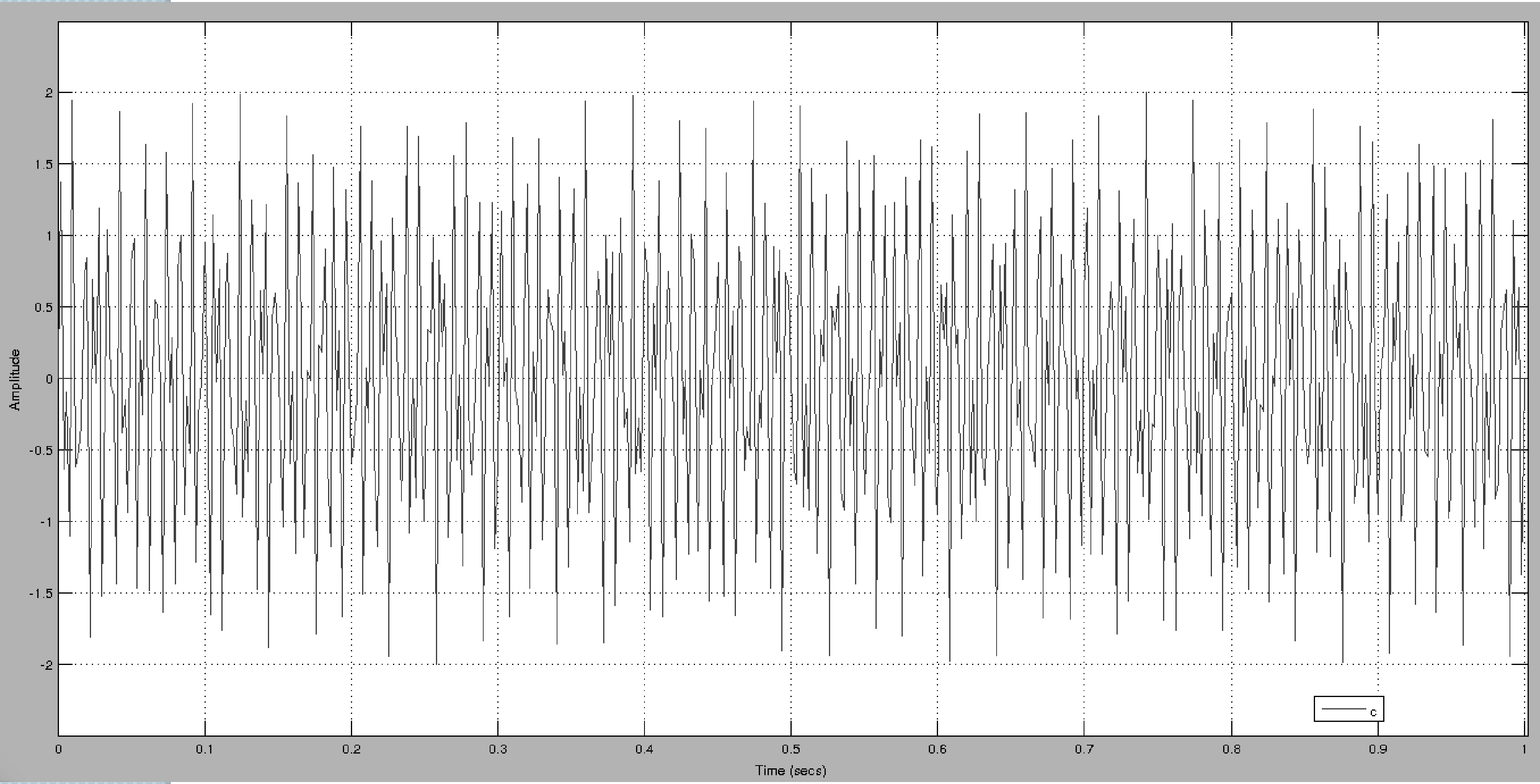

a. Low-pass frequency response
Amplitude
Frequency
1.25
1.00
0.75
0.50
0.25
0.00
0
0.1
0.2
0.3
0.4
0.5
2
4
6
12
8
4 pole
6
4
2


c. High-pass frequency response
Amplitude
Frequency
1.25
1.00
0.75
0.50
0.25
0.00
0
0.1
0.2
0.3
0.4
0.5
2
4
6
4
8
12
2
4
6 pole

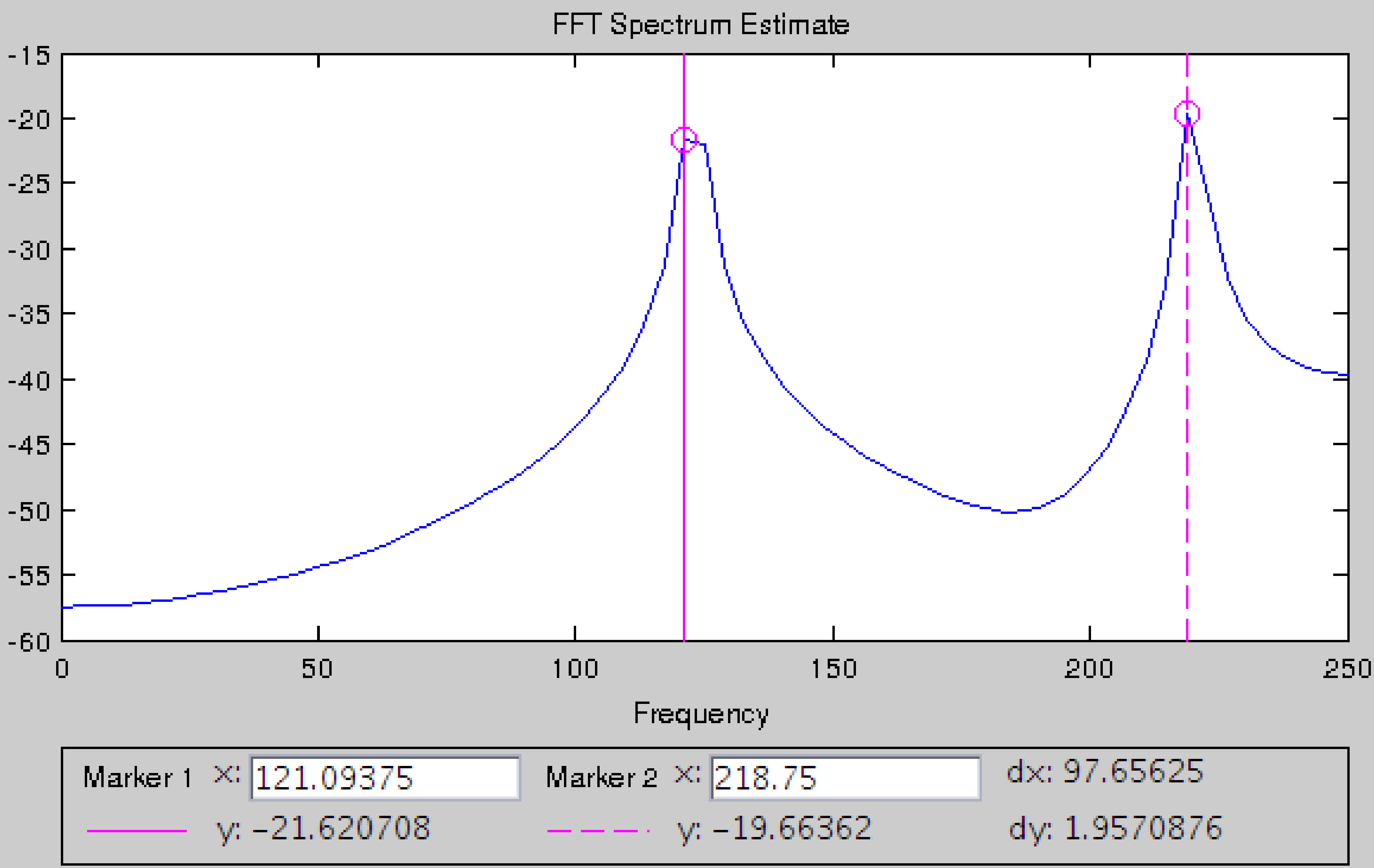
Exercise

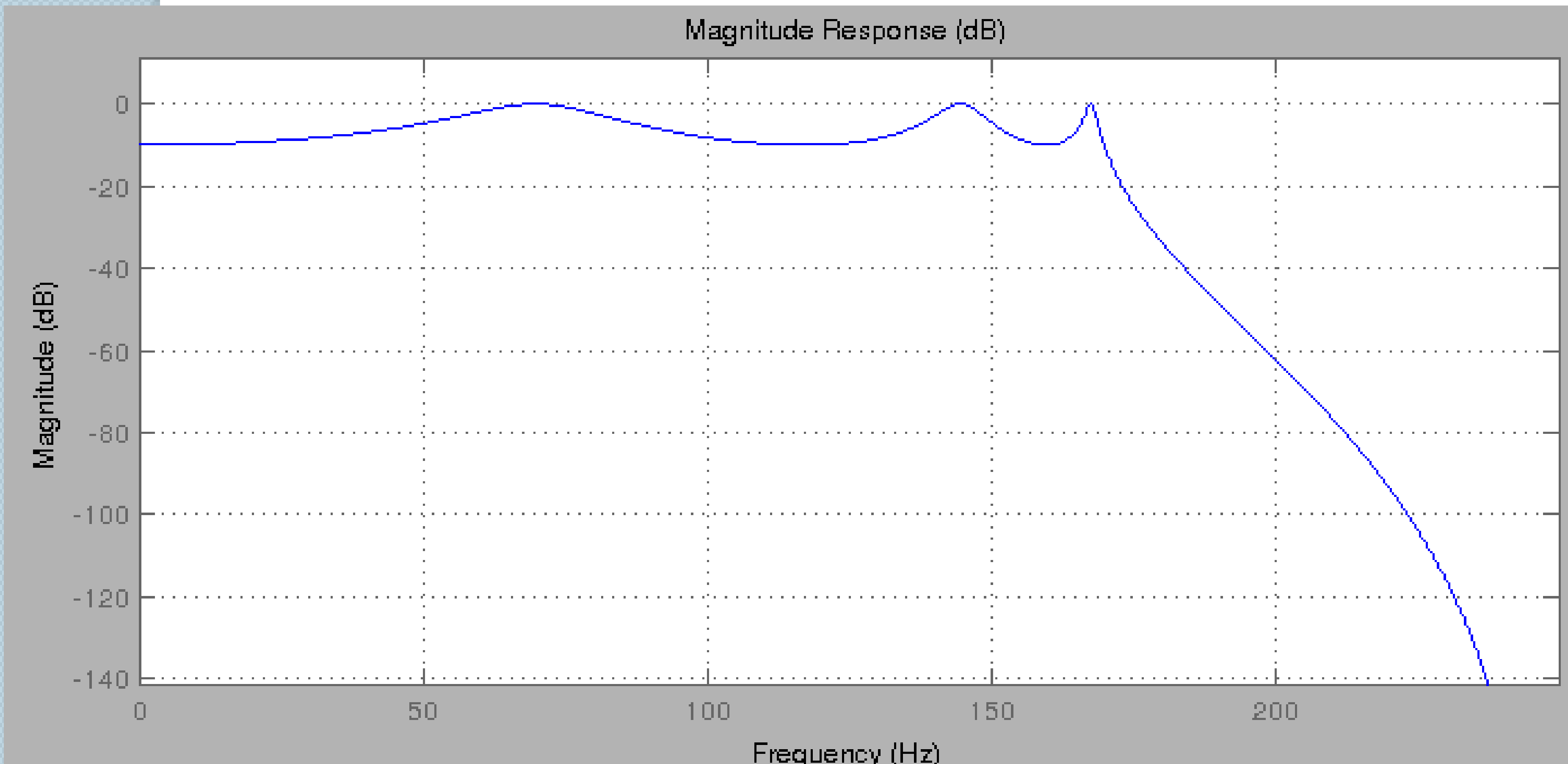
```
sampleRate = 500;
fin = 1;
t = 0:(1/sampleRate):1;
a = sin(2*pi*123*t);
b = sin(2*pi*220*t);
c = a + b;
%plot(t, alphaRythm, '-', t, betaRythm, '-');
plot(t, c, '-')
length(a)

%importar los datos a sptool con una velocidad de muestreo de 500

%----diseño del filtro----
%frec de corte
frec_corte = 170
%m□xima frec a leer
freq_max = sampleRate/2;
%frec normalizada
frec_corte_norm = frec_corte/freq_max;
%orden del filtro
orden = 6;
%rizo del bandpass (decibeles)
bpr = 10;
%coeficientes del filtro
[b a] = cheby1(orden,bpr,frec_corte_norm)
%realizar filtro
filtrada =  filter(b, a, c);
```

```
b =

    0.0228    0.1367    0.3418    0.4557    0.3418    0.1367    0.0228


a =

    1.0000    0.4048    1.4812   -0.0858    1.1157    0.0543    0.6409
```



Amplitude
Time (secs)
c
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

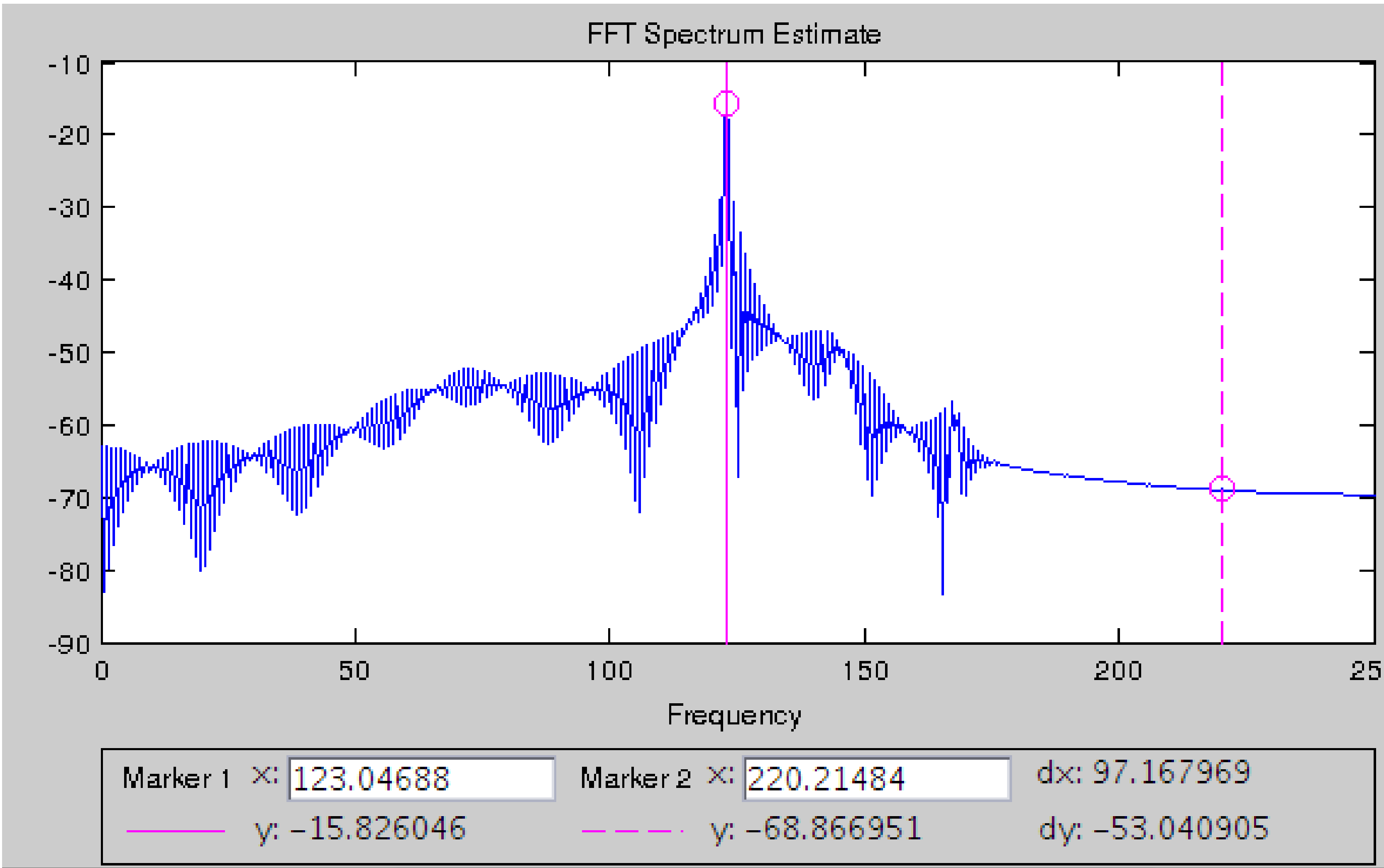

FFT Spectrum Estimate
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
0
50
100
150
200
250
Frequency
Marker 1 x: 121.09375
y: -21.620708
Marker 2 x: 218.75
y: -19.66362
dx: 97.65625
dy: 1.9570876



Magnitude Response (dB)
Magnitude (dB)
Frequency (Hz)
0
-20
-40
-60
-80
-100
-120
-140
0
50
100
150
200

Coeff

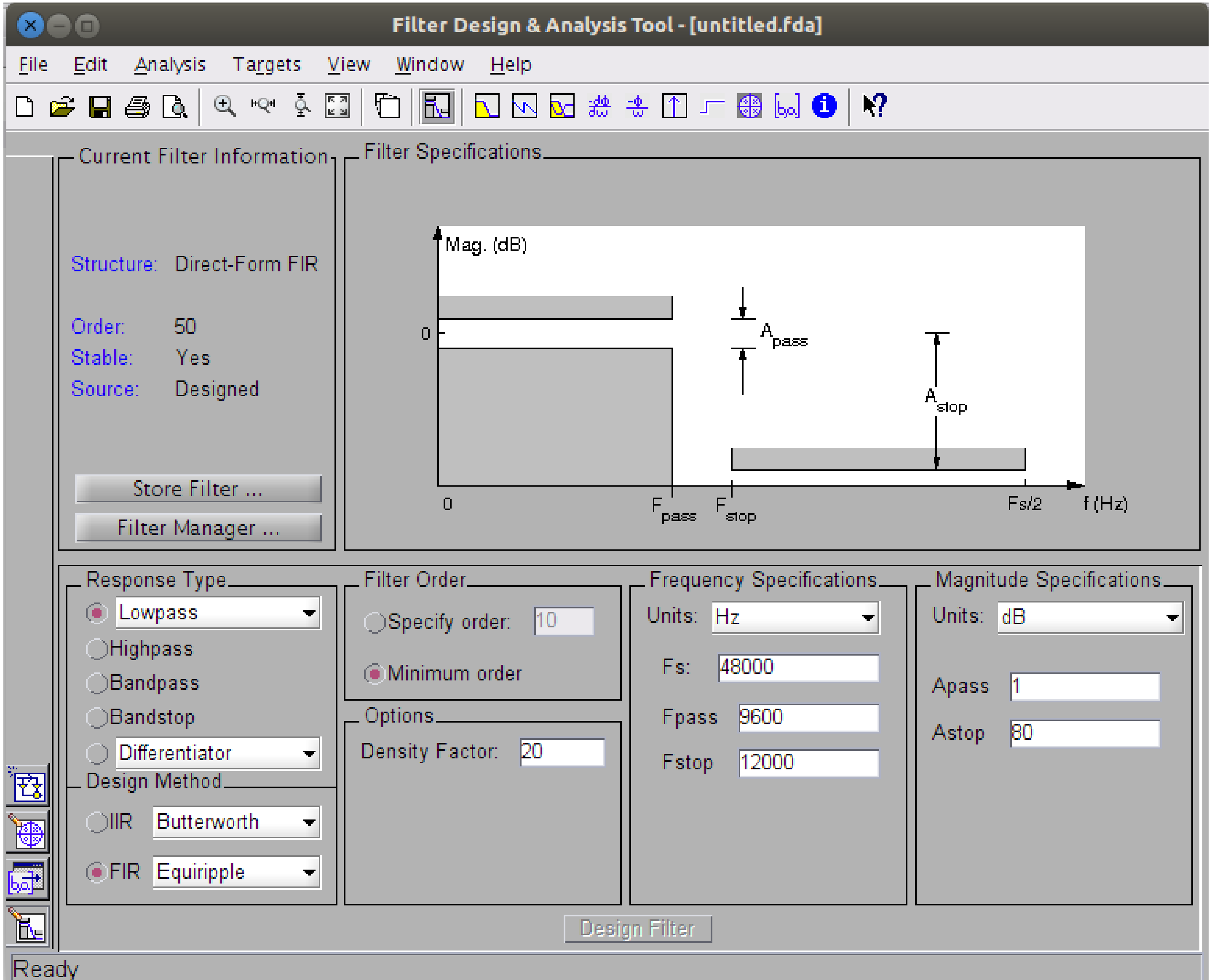
```
Numerator:
0.022784060585876057813958794895370374434
0.136704363515256333005964961557765491307
0.341760908788140860270488019523327238858
0.455681211717521128523600282278493978083
0.341760908788140860270488019523327238858
0.136704363515256333005964961557765491307
0.022784060585876057813958794895370374434
Denominator:
 1
 0.404825131846837660276605674880556762218
 1.481179241824444936526106175733730196953
-0.0857689643218016994907770822464954108
 1.115717219196490139765387539227958768606
 0.054267529355076227215448625429417006671
 0.640949493211831144989787389931734651327
```



FFT Spectrum Estimate
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
50
100
150
200
250
Frequency
Marker 1 x: 123.04688
y: -15.826046
Marker 2 x: 220.21484
y: -68.866951
dx: 97.167969
dy: -53.040905

«… ONE TOOL TO RULE THEM ALL»

fdatool



Filter Design & Analysis Tool - [untitled.fda]
File Edit Analysis Targets View Window Help
Current Filter Information
Structure: Direct-Form FIR
Order: 50
Stable: Yes
Source: Designed
Store Filter ...
Filter Manager ...
Filter Specifications
Mag. (dB)
0
Apass
Astop
0
Fpass
Fstop
Fs/2
f (Hz)
Response Type
Lowpass
Highpass
Bandpass
Bandstop
Differentiator
Design Method
IIR
Butterworth
FIR
Equiripple
Filter Order
Specify order:
10
Minimum order
Options
Density Factor:
20
Frequency Specifications
Units:
Hz
Fs:
48000
Fpass
9600
Fstop
12000
Magnitude Specifications
Units:
dB
Apass
1
Astop
80
Design Filter
Ready