Lowpass / Bandpass filter design

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EECE5356 – Digital Signal Processing
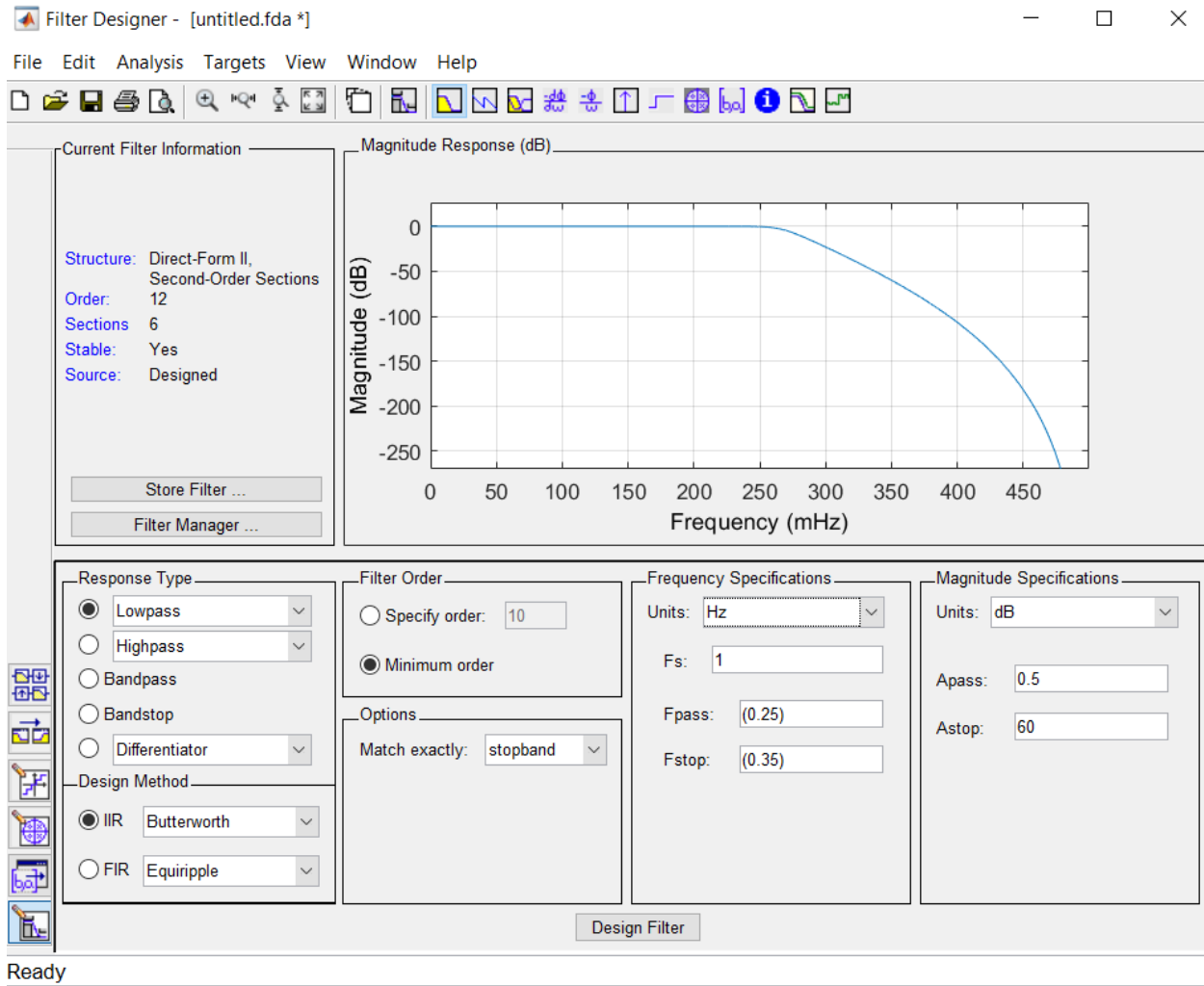
1. Butterworth filter

Figure 1. Butterworth filter and specs. Order: **12**. Since there are no ripples, passband must match exactly -0.5dB, and stopband must match exactly -60dB.
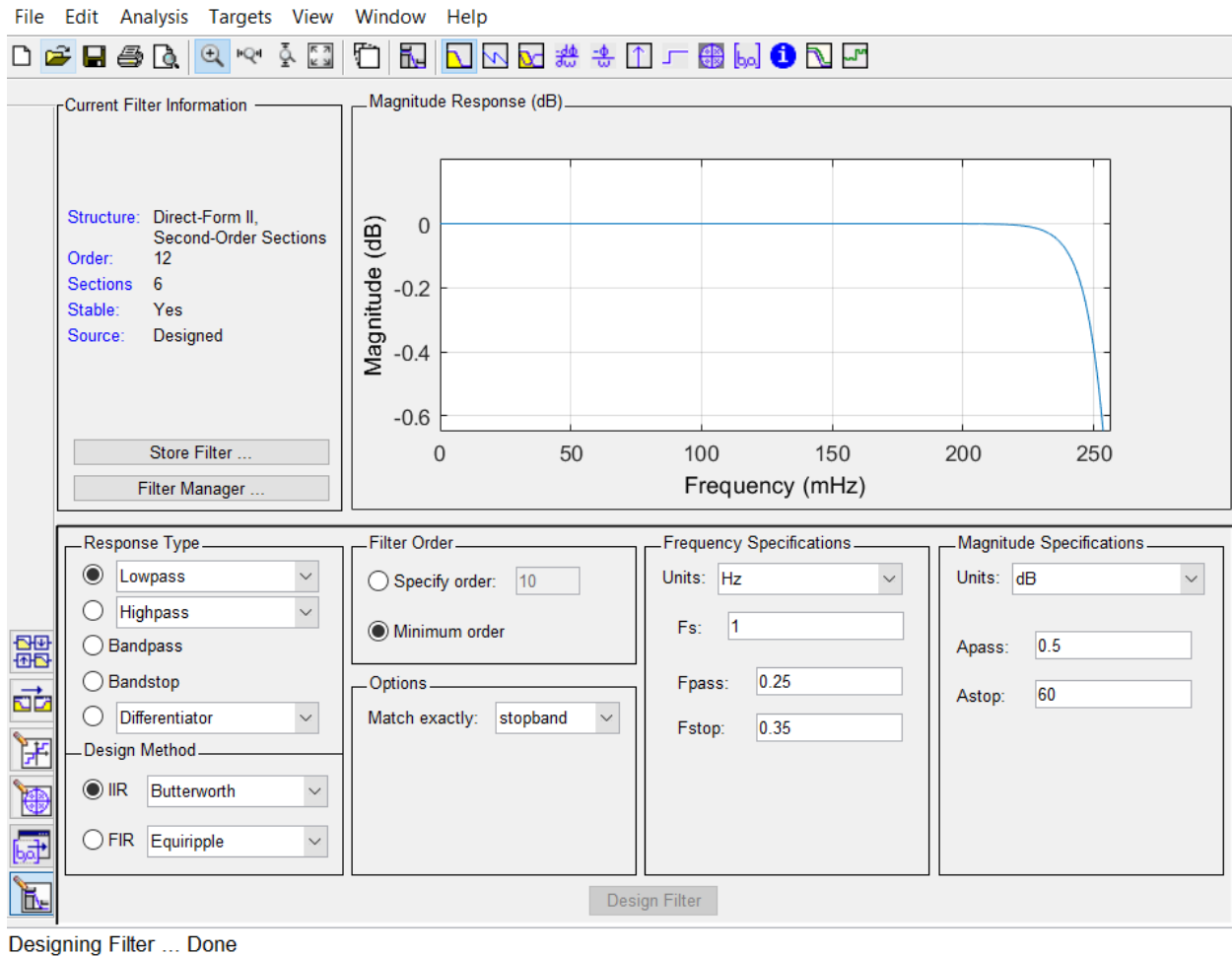
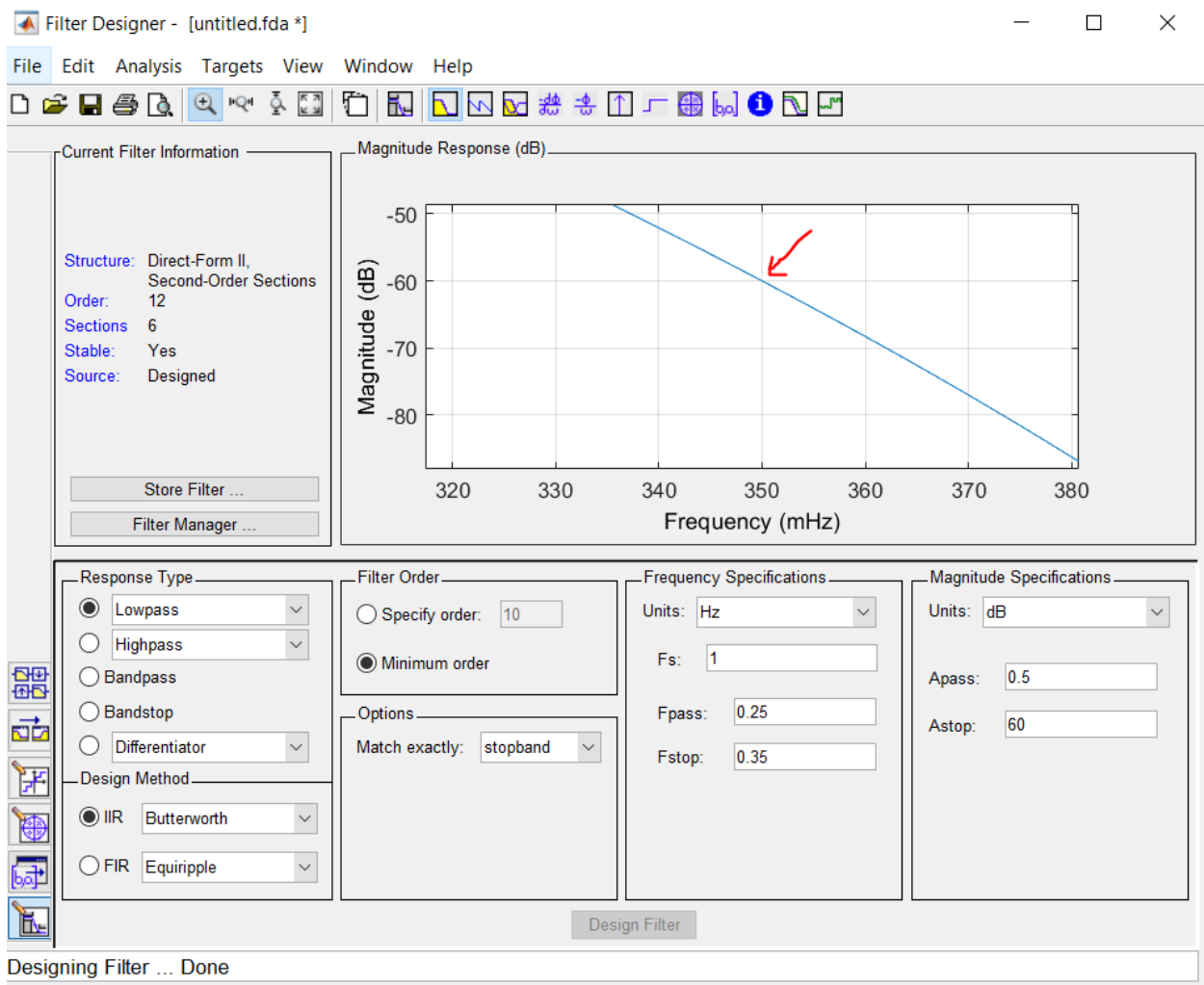Figure 2. Butterworth filter zoomed-in at passband. Magnitude within abs(0.5) dB at 0.25Hz

Figure 3. Butterworth filter zoomed-in at stop band. Magnitude 60dB at 0.35Hz.

Figure 4. Coefficients bwB for numerator, bwA for denominator.
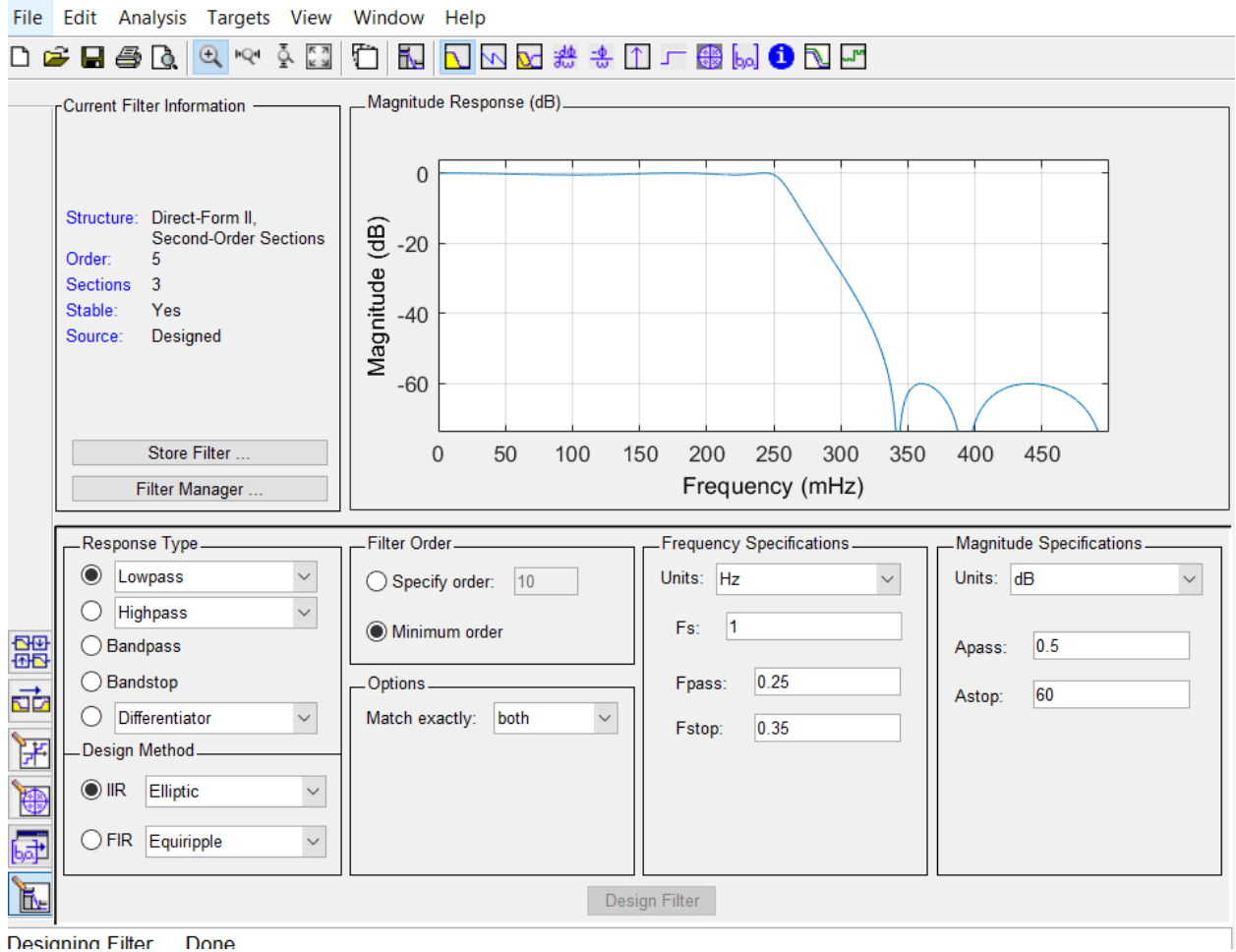
2. Elliptic filter

Figure 5. Elliptic filter and specs. Order: **5**. Since there are ripples, passband must be within 0 to -0.5dB, and stopband max peeks must be less than -60dB.
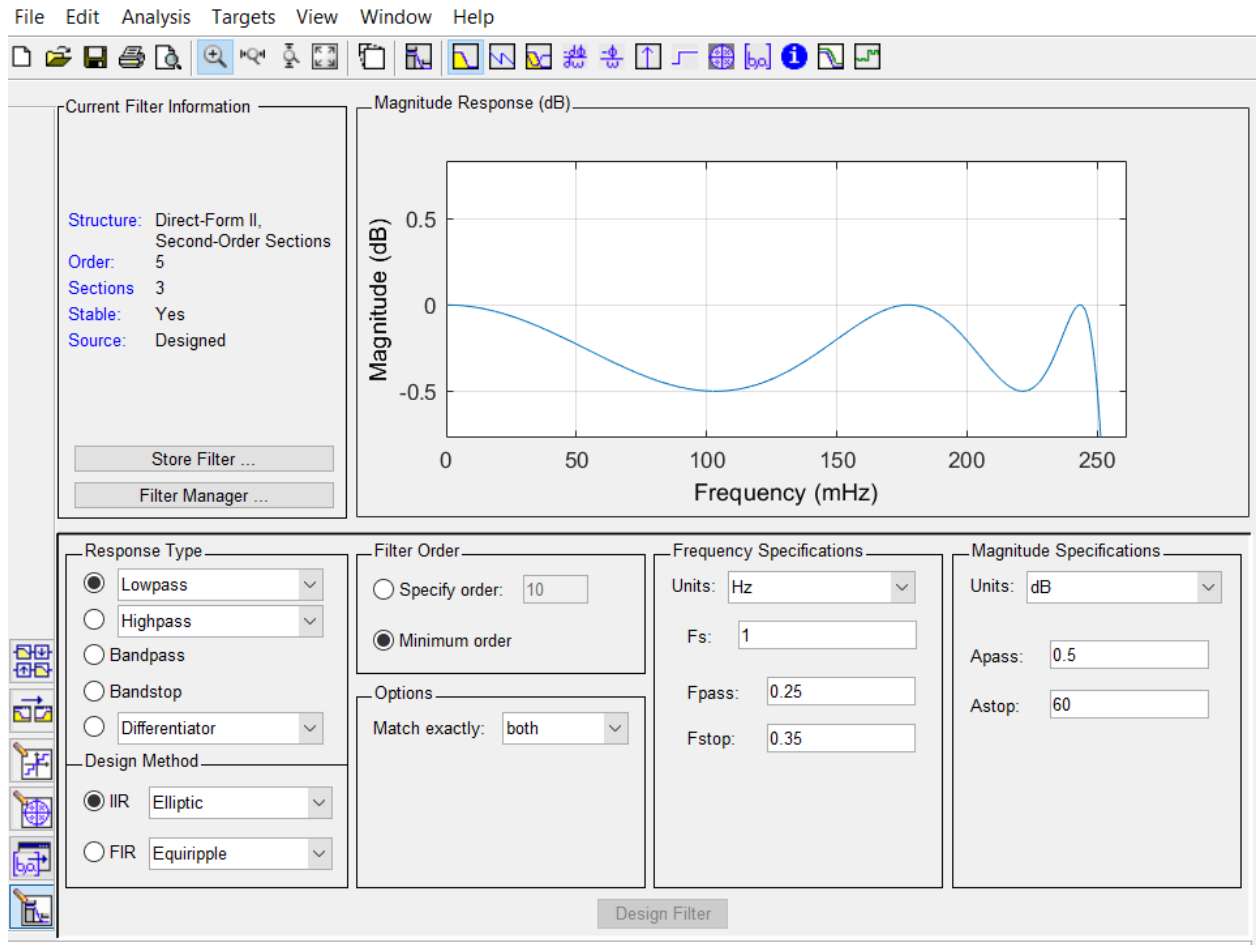
Figure 6. Elliptic filter zoomed-in at passband. Magnitude within abs(0.5) dB from 0Hz - 0.25Hz
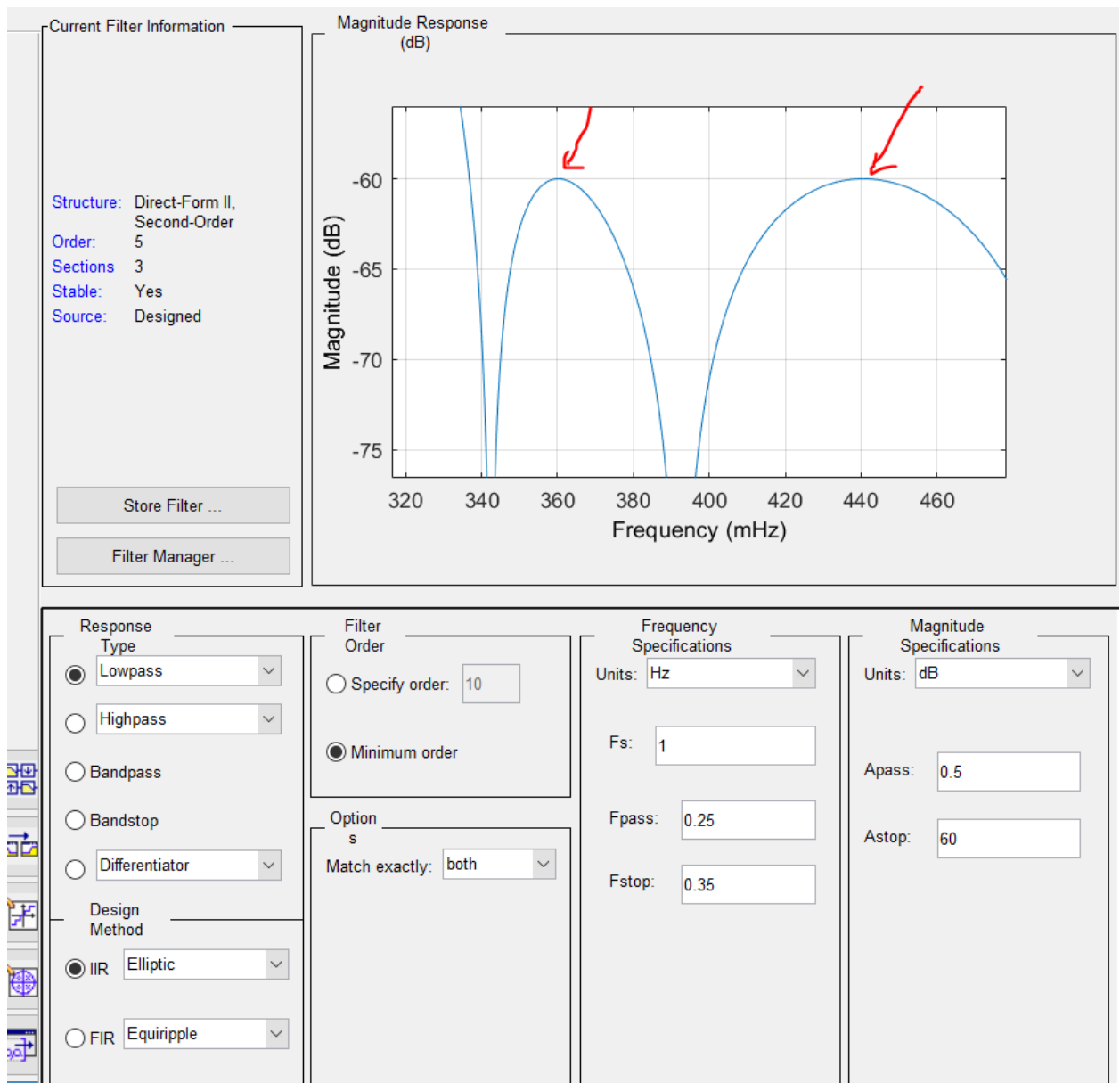
Figure 7. Elliptic filter zoomed-in at stop band. Ripple peeks hit -60dB.

```
>> elipB

elipB =

    0.0496    0.1814    0.3158    0.3158    0.1814    0.0496

>> elipA

elipA =

    1.0000   -0.8291    1.4480   -0.8915    0.5277   -0.1615

>>
```

Figure 8. Coefficients elipB for numerator, elipA for denominator. Order of **5.**
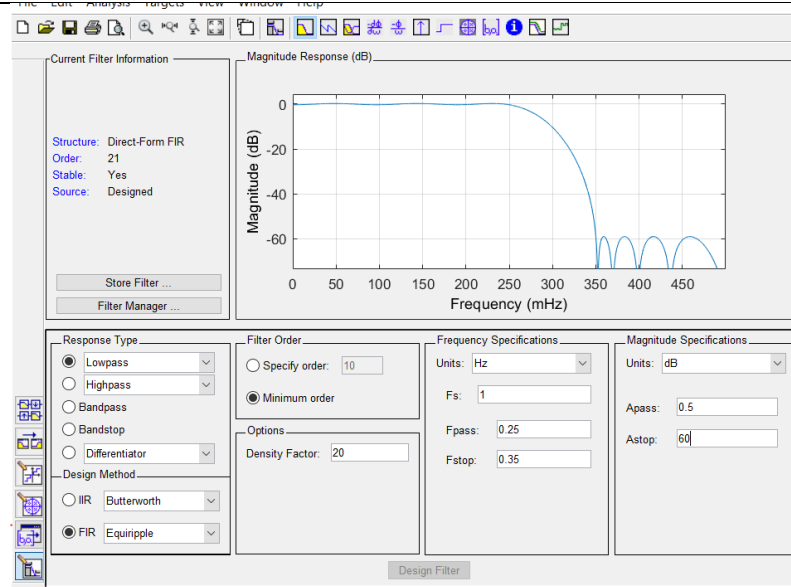
3. **Lowpass FIR**

Figure 9. Lowpass FIR filter. Order **21.** We can see stopband exceeds -60dB.
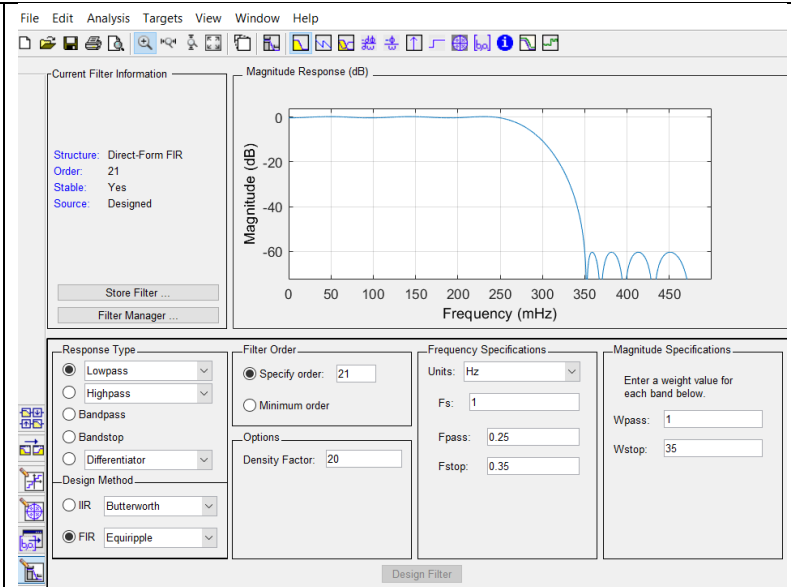

Figure 10. We keep the minimum order of **21**. Adjust the stopband weights for stopband to be smaller than -60dB. Passband weight = 1.
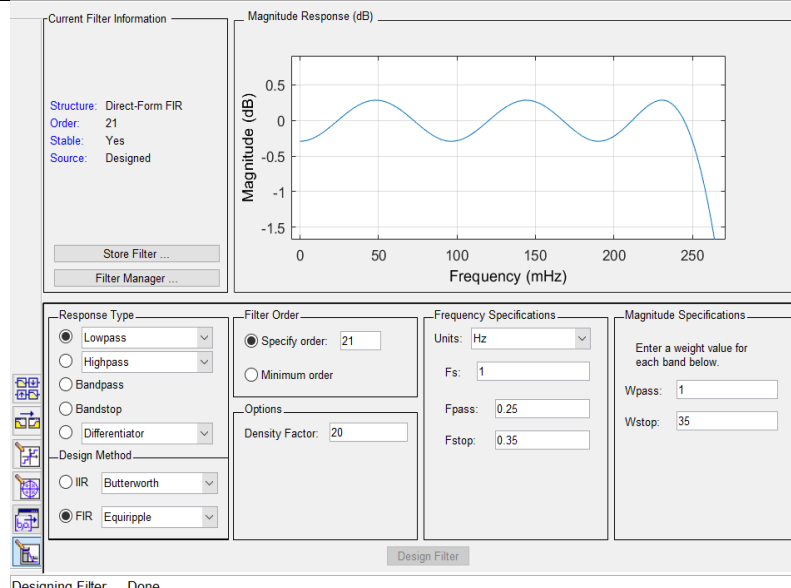

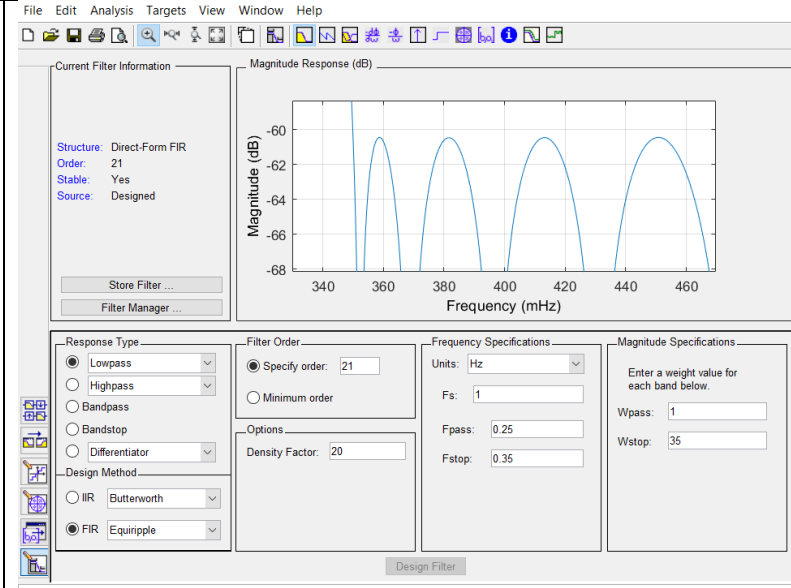Figure 11. Lowpass FIR filter passband zoomed-in. Ripples are within 0 to -0.5dB.

Figure 12. Lowpass FIR filter stopband zoomed-in. Peeks are less than -60dB.

```
>> lowpassFIR_B

lowpassFIR_B =

  Columns 1 through 16

  -0.0094   -0.0163    0.0074    0.0189   -0.0240   -0.0199    0.0555    0.0028   -0.1172    0.0867    0.4989    0.4989    0.0867   -0.1172    0.0028    0.0555

  Columns 17 through 22

  -0.0199   -0.0240    0.0189    0.0074   -0.0163   -0.0094

fx >> |
```

Figure 13. Lowpass FIR coefficient for order of **21**.
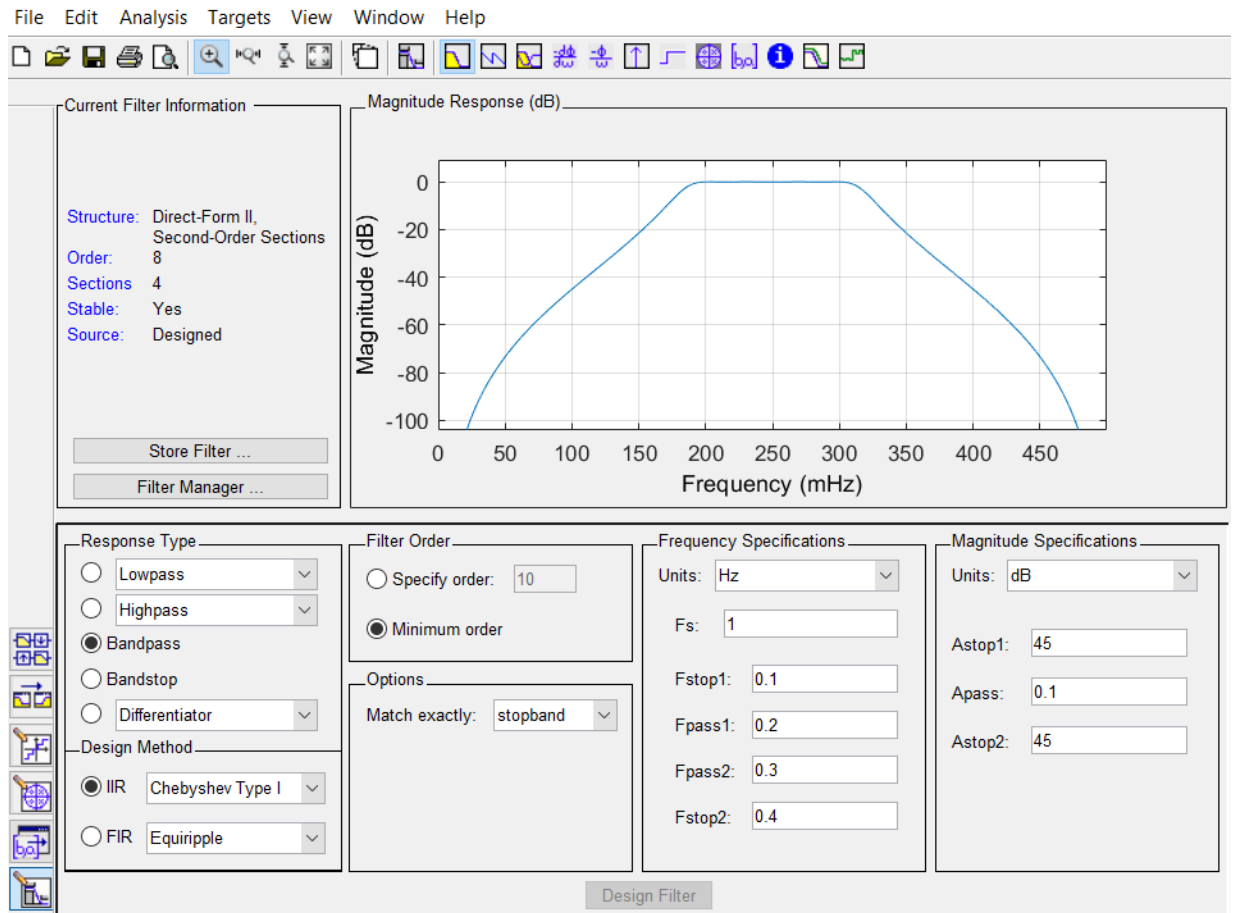
4. Chebyshev Type 1 (IIR)

Figure 14. Chebyshev Type1 filter and specs. Order: **8**. We choose the option of matching exactly 'stopband'
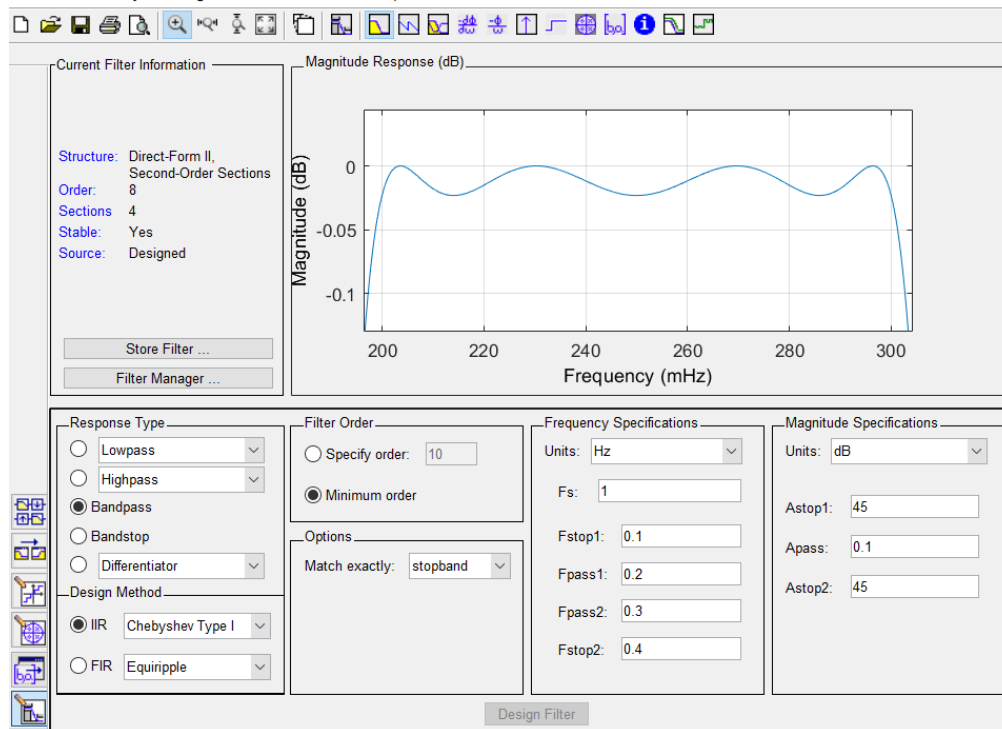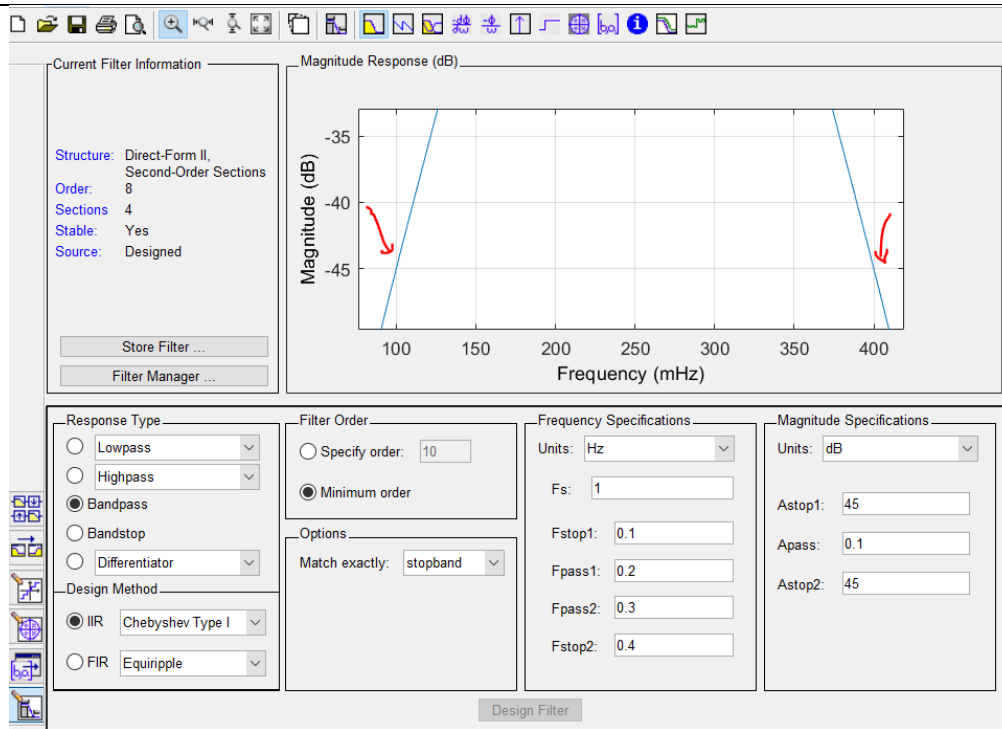
Figure 15. Chebyshev Type 1 passband @0.2Hz and 0.3Hz

Figure 16. Chebyshev Type1 stopband @0.1Hz and 0.4Hz

```
>> chev1B

chev1B =

   0.0081        0   -0.0325        0    0.0488        0   -0.0325        0    0.0081

>> chev1A

chev1A =

   1.0000   -0.0000    2.2381   -0.0000    2.2553    0.0000    1.1098    0.0000    0.2231
```

Figure 17. Chebyshev Type 1 coefficients. Order of **8**.
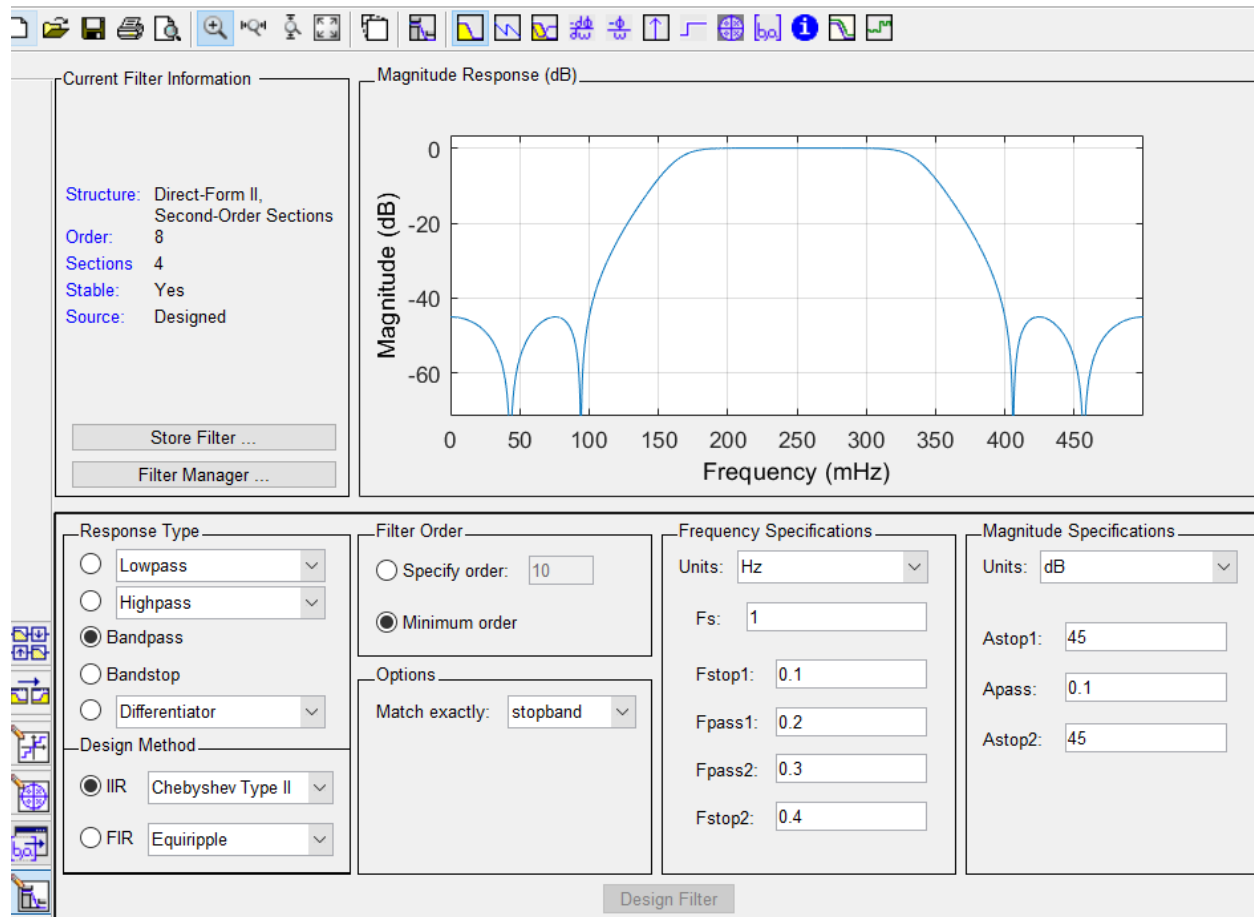
5.   Chebyshev Type 2 (IIR)

Figure 18. Chebyshev Type 2 filter and specs. Order: **8**. We choose the option of matching exactly 'stopband'
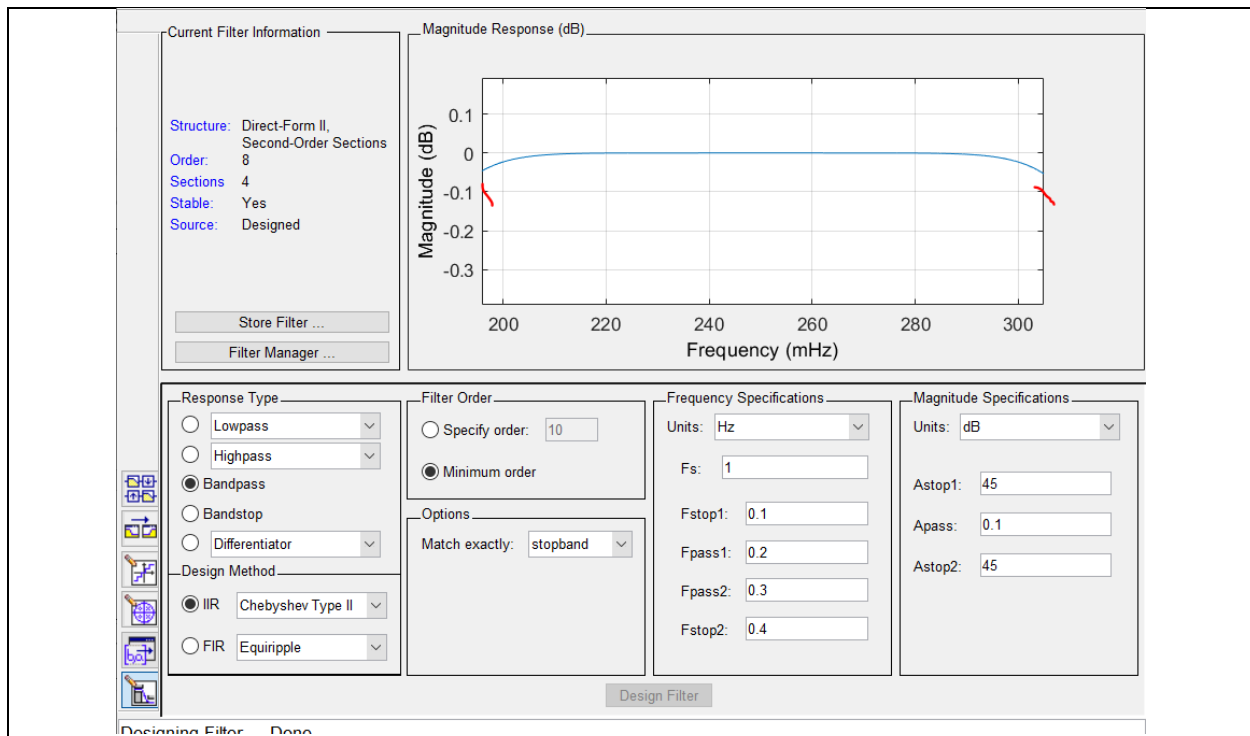
Figure 19. Chebyshev Type 2 passband @0.2Hz and 0.3Hz

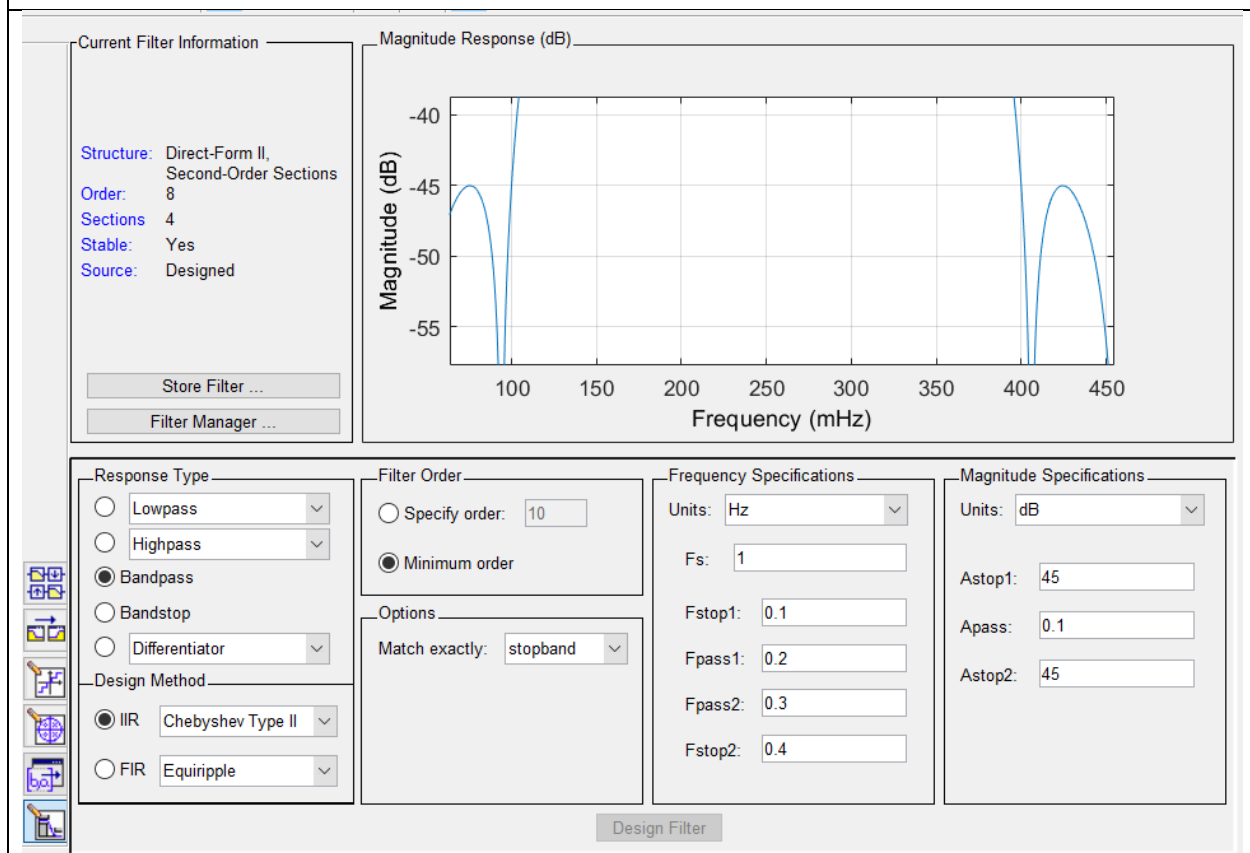Figure 20. Chebyshev Type 2 lobes beyond 0.1Hz and 0.4Hz peek at -45dB.

```
>> chev2B

chev2B =

    0.0534         0   -0.1318         0    0.1759    0.0000   -0.1318         0    0.0534

>> chev2A

chev2A =

    1.0000    0.0000    1.1286    0.0000    0.9173    0.0000    0.2900    0.0000    0.0476
```

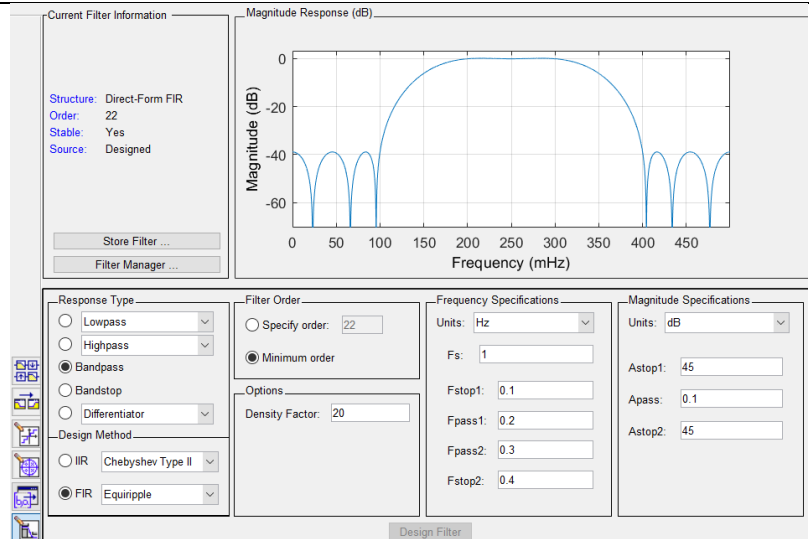Figure 21. Chebyshev Type 2 coefficients. Order of **8**.

6.   Bandpass FIR filter

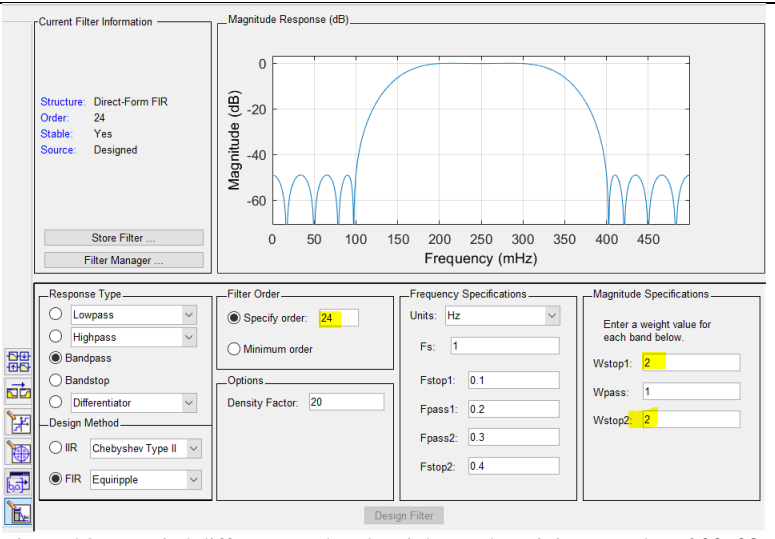Figure 22. Bandpass FIR filter. Order **22**. We can see stopband exceeds -45dB.

Figure 23. We tried different stopband weights at the minimum order of **22, 23, 24** and got the pass/stop weights as above for passband ripples to be within abs(0.1)dB, stopband to be smaller than -45dB.
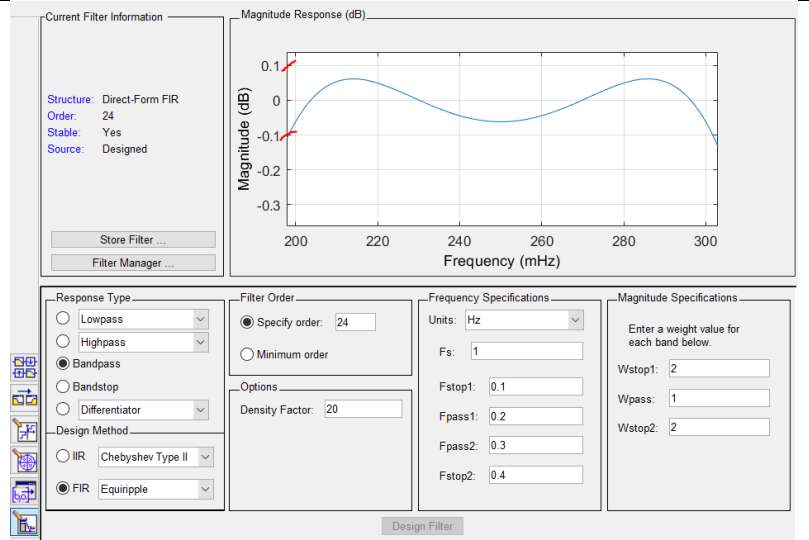

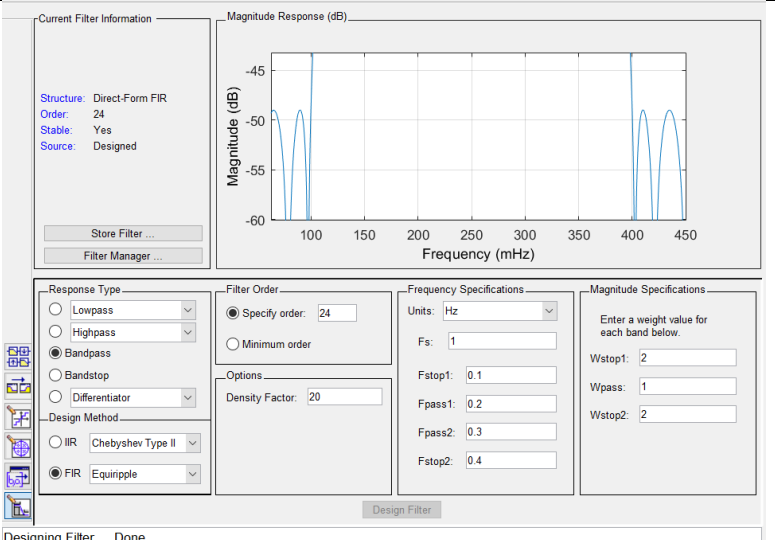Figure 24. Bandpass FIR filter passband zoomed-in. Ripples are within 0.1 to -0.1dB.

Figure 25. Bandpass FIR filter stopband zoomed-in. Peeks are less than -45dB.

s

Figure 26. Bandpass FIR coefficient for order of **24**.