FILTER COEFFICIENT DESIGN
Filter Coefficient Design

- There are many algorithms to find the coefficients for a digital filter. A DSP course will tell you digital filters can be developed that share characteristics with common analog filters such as:
  - Butterworth
  - Chebyshev
  - Bilinear transformation
  - Elliptic

- Some specify no ripple in the pass band or the stop band since this is often a desirable characteristic
Parks-McClellan Method

- Parks-McClellan method is a popular method for designing digital filters
  - Published in the early 70s
  - Iterative
  - Computationally efficient
  - Works by specifying the 1) length of the filter and 2) frequency/magnitude pairs
  - See Oppenheim & Schafer for a thorough discussion
Filter Specification

- Filter specifications are frequently given in dB as min/max attenuation/ripple over frequency regions
- An example filter specification:
  - Low-pass filter
  - Maximum +/- 4dB ripple in passband
  - Sampling frequency is 100 MHz
  - Passband from DC to 12.5 MHz
  - Minimum attenuation 22dB from 19 MHz to 50 MHz
Attenuation and Ripple

- Key filter specifications
  - Min attenuation in stopband
  - Max attenuation in passband
  - Max ripple

\[ \text{ripple} = \text{max} - \text{min} \]
Example Filter

- The same example filter specification getting ready to be entered into matlab:
  - Low-pass
  - Notes:
    - 100 MHz = 2\pi = f_s
    - 50 MHz = \pi
    - 12.5 MHz = 0.25 \pi
    - 19 MHz = 0.38 \pi
  - frequencies specified as fractions of \pi: \[0 \ 0.25 \ 0.38 \ 1]\;
  - corresponding amplitudes: \[1 \ 1 \ 0 \ 0]\;
  - Parks-McClellan ignores every other interval starting with the second one (0.25 \pi – 0.38 \pi). But this is ok—in this example, we don’t care about transition band between 0.25 \pi and 0.38 \pi anyway
  - Use the remez() function in matlab
Example Filter

- 7 coeffs.
Example Filter

- 11 coeffs.
Example Filter

• 21 coeffs.
Example Filter

- 51 coeffs.
Example 21-tap Filter

- \texttt{coeffs = remez(20, [0 0.25 0.30 1], [1 1 0 0]);}
- Notice \texttt{remez} function’s first argument is the number of desired taps minus 1
- \texttt{remez()} for filter design.
  \begin{verbatim}
  >> help remez
  
  to get more information on the matlab function
  \end{verbatim}
- To plot the coefficients, use \texttt{stem(-10:10, coeffs);}
Example Filter Coefficients

- Coefficients of 21-tap filter
- Note sinc() shape in time domain
- Remember this is a low-pass filter which is a rect() in the frequency domain