2020-09-11/MS

Signal Processing, lecture -2

Topics:

- Chebyshev filters
- Brief comparison of Butterworth and Chebyshev filters
- Other filter types
- Impact of group delay variations (examples)

Literature:

Kendall Su: "Analog Filters", Kluwer Academic Publishers, 2nd ed. 2002, ISBN 1-4020-7033-0
The book is available in electronic form at http://www.en.aub.aau.dk.

Topic	Pages ({*} ⇔ supplementary lit.)
Filter design	7-20 (partly repetition)
Chebyshev characteristic	30-36
Chebyshev transfer function	58-62
Filter tables	{App. A}

Supplementary: Lecture presentation "slides"

Exercises:

2.1

A Chebyshev prototype filter is (usually) normalized to a ripple bandwidth of 1 rad/s.
a. Show that the 3 dB bandwidth can be found as:

$$\omega_{3dB} = \cosh\left(\frac{1}{n}\cosh^{-1}\frac{1}{\varepsilon}\right)$$

Hints:

$$\varepsilon^2 C_n^2(\omega_{3dB}) = 1 \quad and$$

$$C_n(\omega) = \cosh(n \cdot \cosh^{-1}\omega) \quad for \quad \omega > 1$$

b. Find the 3-dB bandwidth for a 4th order filter with a 0.5 dB ripple bandwidth of 1 rad/s.

2.2

The requirements for a Chebyshev low-pass filter are:
- Passband ripple: 0.5 dB
- Ripple bandwidth: 20 kHz
- The attenuation at 190 kHz shall be at least 30 dB

a. Find the frequency scaling factor, k_f, and the necessary filter order.
b. Find (analytically) the actual attenuation at 190 kHz
c. Compare the results with Exercise 1.2
d. Find (analytically) the poles of the prototype filter.
e. Check the results of d. with Matlab

f. Use Matlab to plot the transfer function (1 kHz - 1 MHz) and the group delay together with the filter from Exercise 1.2. Note that the frequency scaling factors, k_f, are different for the two filters. Hints: There are many ways to do this. A possible way is shown in Exerc2_2_template.m where $H_{Scaled}(j2\pi f) = H_{Norm}(j\omega_{Norm})$ and $\omega_{Norm} = \frac{2\pi f}{k_f}$.

2.3

A low-pass prototype filter has the transfer function shown.

$$H_{LPP}(s) = \frac{0.423}{(s+0.446)(s^2+0.446s+0.949)}$$

a. Find the location of the poles.
b. Determine which types of filter it is (and explain your conclusion):
   - Butterworth?
   - Chebyshev?

Results:

2.1

a.
b. *1.093 rad/s*

2.2

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a. *125664, 2*
b. *35.95 dB*
c.
d. *-0.713±j1.004*
e.
f.

2.3

a. *-0.446+j0; -0.223±j0.948*
b.