## Chapter 4: Problem Solutions

## Digital Filters

#### Problems on Non Ideal Filters

#### ■ Problem 4.1

We want to design a Discrete Time Low Pass Filter for a voice signal. The specifications are:

Passband  $F_p = 4 \text{ kHz}$ , with 0.8 dB ripple;

Stopband  $F_S = 4.5 \text{ kHz}$ , with 50dB attenuation;

Sampling Frequency  $F_* = 22 \text{ kHz}$ .

Determine a) the discrete time Passband and Stopband, frequencies, b) the maximum and minimum values of  $+H_{-}(\omega)_{-}+$  in the Passband and the Stopband, where  $H_{-}(\omega)_{-}$  is the filter frequency response.

#### Solution

a) Recall the mapping from analog to digital frequency  $\omega = 2 \pi F / F_a$ , with  $F_a$  the sampling frequency. Then the passband and stopband frequencies become  $\omega_p = 2 \pi 4 / 22 \text{ rad} = 0.36 \pi \text{ rad}$ ,  $\omega_a = 2 \pi 4.5 / 22 \text{ rad} = 0.41 \pi \text{ rad}$ ;

b) A 0.8 dB ripple means that the frequency response in the passband is within the interval  $1 \pm \delta$  where  $\delta$  is such that  $20 \log_{10} (1 + \delta) = 0.8$  This yields  $\delta = 10^{0.04} - 1 = 0.096$ . Therefore the frequency response within the passband is within the interval  $0.9035 \le |H(\omega)| < 1.096$ . Similarly in the stopband the maximum value is  $|H(\omega)| < 10^{-50/20} = 0.0031$ 

#### ■ Problem 4.2

A Digital Filter has frequency response H (ω) such that

0.95 s | H ( $\omega$ ) | s 1.05 for 0 s  $\omega$  s 0.3  $\pi$  0 s | H ( $\omega$ ) | s 0.005 for 0.4  $\pi$  s  $\omega$  s  $\pi$ 

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