2006 Paper 8 Question 10

Digital Signal Processing

(*a*) Consider a software routine that converts and records the audio samples received in a digital telephone network call (8 kHz sampling frequency, 8 bit/sample) into a WAV file (8 kHz sampling frequency, 16 bit/sample, uniform quantisation). Your colleague attempted to write a very simple conversion routine for this task, but the resulting audio is very distorted.

(*i*) Name *two* variants of the method used for quantising the amplitude of audio samples in digital telephone networks and explain *one* of them. [4 marks]

(*ii*) Your colleague's routine right-pads each 8-bit data word from the telephone network with eight additional least-significant zero bits to obtain 16-bit values. Explain how this distorts the signal by discussing which frequencies could appear at the output when the incoming telephone signal consists of a pure 1 kHz sine tone. [4 marks]

(*b*) A real-valued discrete random sequence $\{x_i\}$ is fed into a linear time-invariant filter with impulse response $h_0 = 1$, $h_3 = 1$, and $h_i = 0$ for all other i. We observe for the resulting output sequence $\{y_i\}$ the expected value

$$\mathcal{E}(y_{i+k} \cdot x_i) = \begin{cases} 1 & \text{for } k = -1 \\ 2 & \text{for } k = 0 \\ 1 & \text{for } k = 1 \\ 1 & \text{for } k = 2 \\ 2 & \text{for } k = 3 \\ 1 & \text{for } k = 4 \\ 0 & \text{otherwise} \end{cases}$$

What is the value of the autocorrelation sequence $\{\phi_{xx}(k)\}$? [4 marks]

(*c*) The $YCrCb$ colour encoding is used in many image compression methods.

(*i*) How is it defined and why is it used? [4 marks]

(*ii*) Is the conversion from 3×8-bit RGB to 3×8-bit $YCrCb$ coordinates fully reversible? Why? [4 marks]