SS414 2017 Test 1: Check list for the most important stuff

Here is a list of topics that you should understand at this point. It is given with the intention to help – no guarantees however.

Do note the following preliminaries:

- While doing the test you can consult both the handout given to you (Handout 1: Signals and signal analysis), as well as the prescribed handbook (Proakis & Manolakis). You may not use any other notes or sources (except what is stored in your brain).
- The handout and the handbook do not follow the same convention as to the symbols denoting frequency:
  - The handouts denotes frequency in the analog domain with f (cycles per second) and in the discrete time domain as f_ω (cycles per sample). There is one small section around Slide 1.46 that uses F to denote the frequency sampling interval implied by the frequency discretisation in the DFT.
  - The handbook (Proakis& Manolakis) denotes frequency in the analog domain with F (cycles per second) and in the discrete time domain as f (cycles per sample).
- We will follow the notation from the *handout* in this document, as well as in the test.

1 Sampling time signals and the aliasing this introduces

a. Given a continuous time signal $x(t)$ with spectrum $X(f)$, can you sketch the spectrum (including aliasing and changes in magnitude) when we sample it at rate f_s to give a sampled signal $x]n]$? (Slide 1.13)

b. For the above situation, can you overlay f_w with the corresponding f values. Can you also relate these to the corresponding radians-based frequency axes ω and Ω? (Slide 1.30)

2 SQNR due to a finite number of sampling bits

a. Given a signal model description and a specified number of quantisation bits, can you determine the Signal to Quantisation Noise Ratio (SQNR)? (Slides 1.18 - 1.20)

3 The Discrete Time Fourier Transform DTFT

a. Do you know and understand how to use the expression for calculating this? (Slide 1.24)

b. If you were given a simple signal $x[n]$, typically a shortish signal or a sinusoid, can you calculate the DTFT? Do you know how to find the sum of bothe a finite length, as well as an infinite length geometric sequence? This might come in handy to determining closed forms for the DTFT. See tut1 for an example.

c. Do you know and understand the DTFT properties? (Slide 1.28)

4 The period of a sampled sinusoid

a. If you have some continuous time sinusoid $x(t)$ (real or complex valued) with a specified frequency f, and you sample it at a particular frequency f_s, how do you determine whether $x[n]$ will be periodic? (Slide 1.31)

b. If it is periodic, how do you determine its period?

5 Windowing a signal to finite duration

a. What happens in the frequency domain when you sample in the time domain? (Slide 1.41)

b. Do you understand the trade-offs with the various windows you can choose from? (Slides 1.42-1.45)

c. What specifically is the issue with the non-zero width of the main lobe?

d. What specifically is the issue with the non-zero height of the side lobes?

6 The Discrete Fourier Transform (DFT)

a. Can you relate the DFT to the DTFT (Slides 1.46 - 1.47)

b. If you sample the DTFT $X(\omega)$ at frequencies $\omega = \frac{2\pi k}{N}$ with $k = 0 \dots N-1$, how exactly does the corresponding time domain sequence change? What is its period? What happens if we sample at a different number of points than the length of the original sampled signal $x[n]$?

c. Do you understand (as in you can apply it) the DFT properties (Slide 1.48)

d. If you were given a simple signal $x[n]$, typically a shortish signal or a sinusoid, can you calculate the DFT? (Slide 1.49)

e. Why does the DFT $X[k]$ change when you post-zero-pad (i.e. extend it with zeros)$x[n]$? How does this relate to the DTFT $X(\omega)$? Can we really use this to increase frequency resolution? (Slide 1.53)

f. What is the implications for $x[n]$ when you center-zero-pad (i.e. symmetrically add extra zeros in the center section) its DFT $X[k]$?

7 The Short Time Fourier Transform (STFT)

a. Can you interpret a STFT (or spectrogram as it's also known)? (Slide 1.60)

b. Given a specification on frequency resolution, as well as information on the non-stationary behaviour of the signal $x[n]$, can you choose the appropriate segment lengths (N) and shifts (R) to use in your STFT? (Have a look at the tut)

8 The Fast Fourier Transform (FFT)

a. Can you draw the blockdiagram for both DIT and DIF FFTs for $N = 2, 4, 8, 16$ (including all the numeric constants involved)? (P+M pg 535, 539 and Slides 1.65, 1.70)

b. Can you determine the FFT of two N point real sequences using only a single N point FFT and some post processing? (Slide 1.71)

c. Can you determine the FFT of a $2N$ point real sequence, using FFTs of length N and some post processing? (Slide 1.72)

d. Are you able to calculate an IFFT using an FFT routine and some post processing? (Slide 1.73)

9 Up and Down Sampling

a. Can you change the sampling rate of a sampled signal to a new $f'_s = f_s M$ or $f'_s = f_s/M$ with M a positive integer - i.e. both upsampling and downsampling? Remember that on the slides there are missing LPFs, you should also be able to specify them. (Slides 1.74, 1.75)

b. Can you design a sample rate converter using a rational change in rate, i.e. $f'_s = f_s \frac{M}{N}$? (Pay special attention to the cut-off point for the LPF.)

10 Linear vs Circular Convolution

a. Given two signals $x[n]$ and $h[n]$, can you linearly convolve them directly in the sample i.e. $[n]$) domain? (Slides 1.76, 1.77)

b. If the shorter one of the two is post-zero-padded to the length of the other and their convolution is determined via multiplication in the DFT domain, what would the result look like? What is its relationship with the original signals? (Slides 1.80, 1.81, 1.82)

c. Can you apply zero-padding to make the above circular convolution linear? (Slides 1.83, 1.84)

11 Energy vs Power Signals: Correlations and Spectra

a. Given a particular signal, can you calculate its energy (or power) in the time domain, the autocorrelation domain, and frequency domain? (Various Slides starting from 1.85)

b. Do you understand the relationship between convolution and correlation? (Slide 1.88)

c. Can you use correlation to detect signal segments embedded in noise environments? Can you do the math that explains the results of such a cross-correlation system? (See prac).