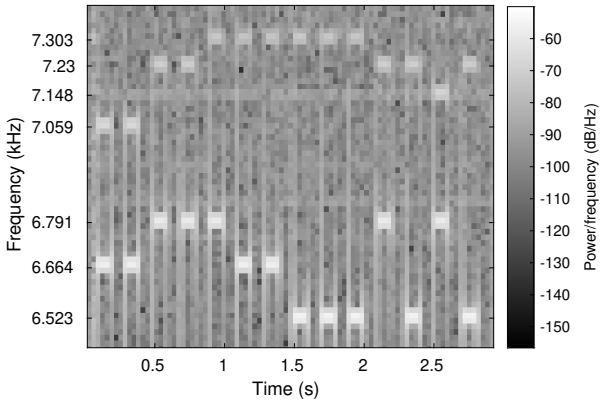
11 Digital Signal Processing (mgk25)

This question can only be attempted by Part II 50% candidates.

You are the new CTO of *Missampled Ltd*, a consulting company specializing in fixing digital-signal-recording accidents. These are the first customers seeking your help:

(*a*) A police officer has recorded a conversation between suspects on an analog phone line. The recording $\{x_n\}$ has sampling frequency $f_s = 16$ kHz. But the officer had accidentally activated a "scramble" switch on the recorder, and as a result the recording now sounds high-pitched and is unintelligible.



The manual of the recorder does not explain what the "scramble" switch does. Using a spectrogram (above), you spot at the start of the recording a sequence of 14 tone pairs.

(*i*) What six computational steps are typically involved in producing such a spectrogram from a sequence of real-valued samples? [6 marks]

(*ii*) The spectrogram reminds you of DTMF-encoded touch-tone digits, but the frequencies are clearly not the standard ones at 697, 770, 852, 941, 1209, 1336, and 1477 Hz. What appears to have happened to the frequencies in this recording, how can this transformation be explained as a simple time-domain operation on its samples, and how can you then restore it such that the officer can hear the original voices again? [6 marks]

(*b*) A TV producer discovered that during the recording of a stage production, one of the microphones accidentally had activated the following digital FIR filter (where $\{x_n\}$ is the desired audio signal and $\{y_n\}$ is the available recorded sequence):

$$y_n = 0.4 \times \left(x_n + x_{n-1} + \frac{1}{2} x_{n-2} \right)$$

(*i*) What is the z-transform $H(z)$ of the impulse response of this filter? [2 marks]

(*ii*) What is the z-transform of the impulse response of a filter G that, if applied to the recorded samples $\{y_n\}$, converts them back into the original waveform $\{x_n\}$? [2 marks]

(*iii*) Draw a Direct Form I representation of G. [4 marks]