EE 627 - Speech Signal Processing

Assignment # 1

1. The autocorrelation function for a real-valued stable sequence x[n] is defined as

$$c_{xx}[n] = \sum_{k=-\infty}^{\infty} x[k]x[n+k].$$

a) Show that the z-transform of $c_{xx}[n]$ is

$$C_{xx}(z) = X(z)\,X(z^{-1}).$$

Determine the region of convergence for $C_{xx}(z)$.

b) Suppose that $x[n] = a^n u[n]$. Sketch the pole-zero plot for $C_{xx}(z)$, including the region of convergence. Also find $c_{xx}[n]$ by evaluating the inverse z-transform of $C_{xx}(z)$.

2. Suppose

$$x[n] = \sum_{k=-\infty}^{\infty} \delta[n-kP].$$

Show that the Fourier transform of x [n] is given by

$$X(\omega) = \sum_{k=-\infty}^{\infty} \frac{2\pi}{P}\delta(\omega - \frac{2\pi}{P}k).$$

3. What differentiates the five unvoiced fricatives |*f*| , |*T*| , |*s*| , |*S*| , |*h*| ? Why are fricatives lower in energy than vowels?

4. (MATLAB) In this MATLAB exercise, you investigate some properties of a windowed speech waveform. Load the workspace *ex2Ml.mat* and plot the speech waveform labeled *speech1_10k*. This speech segment was taken from a vowel sound that is approximately periodic (sometimes referred to as "quasi-periodic"), is 25 ms in duration, and was sampled at 10000 samples/s.Plot the log-magnitude of the Fourier transform of the signal over the interval $[0, \pi]$, using a 1024-point FFT. The signal should be windowed with a Hamming window of two different durations, 25 ms and 10 ms, with the window placed, in each case, at the signal's center. Show the log-magnitude plot for each duration. In doing this exercise, use MATLAB functions *fft.m* and *hamming.m*.

5. (MATLAB) In this MATLAB exercise, you design a number of glottal pulse trains with different shapes and pitch, and analyze their spectral and perceptual properties.

a) Create in MATLAB the following glottal pulse, which is a time-reversed decaying exponential convolved with itself:

$$g[n] = (\alpha^{-n} u[-n]) * (\alpha^{-n} u[-n]).$$

Set the length of g[n] to where it has effectively decayed to zero. Experiment with the different values of α = 0.9, 0.95, 0.99, 0.998 and compute the resulting Fourier transform magnitude, using a FFT length sufficiently long to avoid significant truncation of the pulse.

b) Convolve $g[n]$ from part (a) (with $a = 0.99$) with a periodic impulse train of pitch 100 Hz and 200 Hz. Assume an underlying sampling rate of 10000 samples/s. Using the MATLAB *sound.m* function, listen to the two pulse trains and make a perceptual comparison. Window a 20-ms piece (with a Hamming window) of the waveform and compare the spectral envelope and harmonic structure for the two pitch selections.