The University of Queensland
School of Information Technology & Electrical Engineering

COMS3100/7100 Introduction to Communications

Tutorial 3

These exercises relate to material in Lectures 8–9, but also CCR, ch. 4.

Exercises:

★ 3.1 Show that baseband equivalent signals are not time invariant with respect to the corresponding bandpass signal. That is, given two bandpass signals $f(t)$ and $g(t)$ such that $f(t) = g(t - t_0)$, show that it is not true in general of the corresponding baseband equivalent signals $\breve{f}(t)$ and $\breve{g}(t)$ that $\breve{f}(t) = \breve{g}(t - t_0)$. What is the correct relationship?

3.2 Consider a signal of the form

$$x(t) = \sum_{i=1}^{n} A_i \delta(t - t_i)$$

which is passed through an ideal bandpass filter with centre frequency f_c and bandwidth $2W$ to produce the bandpass signal $g(t)$. Using your solution to Question 3.1, find an expression for the equivalent baseband signal $\breve{g}(t)$.

3.3 In Lecture 8, a block diagram was shown of a direct-conversion modulator for creating a bandpass signal from in-phase and quadrature baseband components. Show that this design can be modified so that, instead of using a sinusoid for mixing the baseband components, any periodic signal could be used. Show that the necessary condition for correct operation is that the signal used for mixing the quadrature component be delayed by one quarter of a period relative to that used for mixing the in-phase component.

Hint: The main modification that needs to be made to the design, apart from what is indicated above, is a band-pass filter on the output.

★ 3.4 A simple parallel resonant RLC bandpass filter (as illustrated in CCR Figure 4.1-7, p. 150) has a frequency response that can be closely approximated as

$$H(f) = \frac{1}{1 + j2Q\Delta}$$

where $\Delta = (f - f_c)/f_c \ll 1$, f_c is the resonant frequency and Q is the quality factor. The signal $v_{in}(t) = A\cos(2\pi f_c t)u(t)$ is applied to the filter.

(a) Determine the baseband equivalent input, output and impulse response, $\check{v}_{\text{in}}(t)$, $\check{v}_{\text{out}}(t)$ and $\check{h}(t)$, respectively.

(b) Hence, determine the output $v_{\text{out}}(t)$ and sketch it.

★ 3.5 (a) Under the assumption that the message $x(t)$ has no DC component, *i.e.*, that $\langle x(t)\rangle = 0$, show that at least half of the power in the AM signal is not dependent on the message, *i.e.*, that at least half of the power is consumed by transmission of the carrier. *Hint:* Recall that $\cos^2 2\pi f_c t = \frac{1}{2} + \frac{1}{2}\cos 4\pi f_c t$.

(b) Why is AM impractical for transmission of messages with a significant DC component?

3.6 Let $x(t) = u(t)\cos 2\pi f_m t$ with $f_m \ll f_c$.

(a) Sketch the AM signal $x_c(t)$ generated from the message $x(t)$ and indicate the envelope when $\mu < 1$ and $\mu > 1$.

(b) Sketch the DSB-SC signal.

Identify locations where any phase reversals occur.

★ 3.7 Calculate the transmitted power of an AM wave with 100 percent tone modulation, *i.e.*, $\mu = 1$ and a message consisting of a unit amplitude sinusoid (*tone*), and peak envelope power of 32 kW.