GLASGOW COLLEGE UESTC

Exam paper

Communications Principles and Systems (UESTC3018)

Date: Dec.17th, 2021
Time: 7:00-9:00pm

Attempt all PARTS. Total 100 marks

Use one answer sheet for each of the questions in this exam.
Show all work on the answer sheet.

Make sure that your University of Glasgow and UESTC Student Identification Numbers are on all answer sheets.

An electronic calculator may be used provided that it does not allow text storage or display, or graphical display.

All graphs should be clearly labelled and sufficiently large so that all elements are easy to read.

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

FORMULAE SHEET IS PROVIDED AT THE END OF PAPER

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Q1 (a) Sketch the block diagrams of analogue and digital communication systems demonstrating the major components of both. [10]

(b) Discuss and justify design optimality and information scalability that digital communication systems exhibit compared to analogue ones. [6]

(c) Consider the passband signal

$$x(t) = A\text{sinc}(Wt)\sin[2\pi f_0 t].$$

i) Derive the mathematical condition between f_0 and W for it to be passpand. [6]

ii) Find the bandwidth of $x(t)$. [3]

Q2 Consider the signal

$$x(t) = A\cos(2\pi f_m t + \phi)\cos(2\pi f_c t), \text{ where } A > 0,\ 0 \le \phi < \pi/2,\ f_c > f_m.$$

(a) Find the Fourier transform (FT) of $x(t)$. [3]

(b) Assume $x(t)$ is the outcome of analogue amplitude modulation (AM).

i) Identify the AM category and find the message signal. [3]

ii) If $x(t)$ is filtered by a high-pass filter with cut-off frequency $f_c + 0.9 f_m$, identify the AM category and determine the FT of the filtered version of $x(t)$. [3]

iii) Determine and plot the real and imaginary parts of the FTs of the lower side-band (LSB) and upper side-band (USB) AM signals arising from $x(t)$. [6]

iv) Derive the time domain expressions for the LSB and USB AM signals arising from $x(t)$. [6]

(c) Consider the conventional analogue AM signal

$$y(t) = x(t) + \cos(2\pi f_c t).$$

If $y(t)$ is passed through an envelope detector, determine the range of A for correct message recovery. [4]

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Q3 Consider the signal

$$z(t) = \cos\left[500\pi t + 400\pi \int_0^t \operatorname{sinc}(W\tau)d\tau\right], \text{ where } t \text{ (msec) and } W \text{ (KHz).}$$

(a) Determine the message signals if $z(t)$ is the outcome of: i) analogue frequency modulation (FM), ii) analogue phase modulation (PM). [4]

(b) If $z(t)$ is the outcome of analogue FM, find the approximate range of W. [12]

(c) Sketch the block diagram of the discriminator system that implements analogue frequency demodulation. [3]

(d) If $z(t)$ is the input to the discriminator system, prove that the message signal can be correctly extracted. [6]

Q4 Consider the modulating baseband signal

$$p(t) = \operatorname{sinc}(Wt)$$

(a) Provide the mathematical formulas for the passband and its equivalent baseband signal for each transmission and sketch the constellation diagrams for the following digital modulation techniques:

i) 4-Amplitude Shift Keying (4-ASK) with antipodal signaling. [4]

ii) Quadrature Phase Shift Keying (QPSK). [4]

iii) 16-Quadrature Amplitude Modulation (16-QAM) with rectangular constellation. [4]

(b) Find two (2) QPSK and two (2) 4-ASK techniques contained in the 16-QAM providing their respective mathematical formulas and demonstrating their constellation diagrams. [8]

(c) Find W to achieve 12 Mbps bit rate using the 16-QAM and avoiding intersymbol interference. [5]

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FORMULAE SHEET

Common Functions

- Sinc function: $\mathrm{sinc}(x) = \dfrac{\sin(\pi x)}{\pi x}$
- $\min[\mathrm{sinc}(x)] = \mathrm{sinc}(\pm 1.43) = -0.2172$
- $\max[\mathrm{sinc}(x)] = \mathrm{sinc}(0) = 1$
- Indicator function: $I_{[a,b]}(x) = \begin{cases} 1, & a \le x \le b \\ 0, & otherwise \end{cases}$

Fourier and Inverse Fourier Transforms

Definitions

- Fourier Transform (FT): $S(f) = \int_{-\infty}^{\infty} s(t) e^{-j2\pi ft} dt$
- Inverse Fourier Transform (IFT): $s(t) = \int_{-\infty}^{\infty} S(f) e^{j2\pi ft} df$
- Notation: $s(t) \leftrightarrow S(f)$

Properties

- Time Shifting: $s(t - t_0) \leftrightarrow S(f) e^{-j2\pi f t_0}$
- Frequency Shifting: $s(t) e^{j2\pi f_0 t} \leftrightarrow S(f - f_0)$
- Modulation (cosine): $s(t)\cos(2\pi f_c t) \leftrightarrow \dfrac{1}{2}[S(f - f_c) + S(f + f_c)]$
- Modulation (sine): $s(t)\sin(2\pi f_c t) \leftrightarrow \dfrac{1}{2j}[S(f - f_c) - S(f + f_c)]$

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Pairs

- $\delta(t - t_0) \leftrightarrow e^{-j2\pi f t_0}$
- $e^{j2\pi f_0 t} \leftrightarrow \delta(f - f_0)$
- $W\,\mathrm{sinc}(Wt) \leftrightarrow I_{[-W/2,W/2]}(f)$
- $I_{[-T/2,T/2]}(t) \leftrightarrow T\,\mathrm{sinc}(Tf)$
- $\cos(2\pi f_c t) \leftrightarrow \frac{1}{2}[\delta(f - f_c) + \delta(f + f_c)]$
- $\sin(2\pi f_c t) \leftrightarrow \frac{1}{2j}[\delta(f - f_c) - \delta(f + f_c)]$

Laplace Transforms

- Definition: $G(s) = \int_0^\infty g(t)e^{-st}dt$
- Notation: $g(t) \rightleftarrows G(s)$
- Integration Property: $\int_0^t g(\tau)d\tau \rightleftarrows \frac{1}{s}G(s)$
- Step Function: $u(t) \rightleftarrows 1/s$, $\mathrm{Re}(s) > 0$
- Final Value Theorem: $\lim_{t\to\infty} g(t) = \lim_{s\to 0}[sG(s)]$

End of question paper