GLASGOW COLLEGE UESTC

Exam paper

Communications Principles and Systems (UESTC3018)

Date: 4th Jan. 2021
Time: 09:30am - 11:30am

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 identifying the major components of both. [10]

(b) Compare analogue and digital communication systems in terms of complexity and justify the dominance of digital communications. [6]

(c) Consider the signals

$$x(t) = 10 \cdot \sin[40\pi t + (\pi/6)]\text{, where } t \text{ is in } msec.$$

$$y(t) = \sin[4.8\pi t + (\pi/4)]\text{, where } t \text{ is in } nsec.$$

$$z(t) = x(t) \cdot \mathrm{y(t)}.$$

i) Derive the equivalent baseband signal (the complex envelope) of $z(t)$ and prove that $z(t)$ is passband. [6]

ii) Compute the bandwidth of $z(t)$. [3]

Q2 Consider the signal

$$x(t) = A\mathrm{sinc}(Wt) \cdot \cos(20\pi t)\text{, where } t \text{ is in } \mu sec.$$

(a) Determine the spectrum $|X(f)|$ of $x(t)$ and the range of W in order $x(t)$ to be passband. [6]

(b) Assume $x(t)$ is the result of amplitude modulation (AM) and W is half to its maximum value for $x(t)$ to be passband.

i) Compute the bandwidth of $x(t)$ and plot its spectrum $|X(f)|$. [6]

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

iii) If $x(t)$ is filtered by a high pass filter with 10 *MHz* cut-off frequency, determine the AM category and compare the bandwidth of the filtered signal with that of the original signal $x(t)$. [4]

(c) The following signal is the result of conventional AM

$$y(t) = 5\cos(20\pi t) + A\mathrm{sinc}(0.02t) \cdot \cos(20\pi t),\ A > 0\text{, where } t \text{ is in } \mu sec.$$

Find the message signal and determine the range of A for accurate message recovery when $y(t)$ is passed through an envelope detector. [6]

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Q3 Consider the following signal is the result of frequency modulation (FM)

$$u_{FM}(t) = \cos\left[200\pi t + A \cdot \int_0^t \mathrm{sinc}(0.01\tau)d\tau\right],\ A > 0\text{, where } t \text{ is in } \mu sec.$$

(a) Find the message signal and determine its spectrum. [3]

(b) Determine the range of A when the available bandwidth for FM transmissions is less than 0.2 *MHz*. [9]

(c) Sketch the block diagram of the discriminator system that implements frequency demodulation demonstrating its components and operations. [3]

(d) Prove that the message signal can be correctly extracted by the discriminator when the bandwidth of FM transmissions is less than 0.2 *MHz*. [10]

Q4 Consider the modulating baseband signal

$$p(t) = \mathrm{sinc}(20t)\text{, where } t \text{ is in } \mu sec.$$

(a) Provide mathematical formulas for both the baseband and passband signals in any transmission and sketch the constellation diagrams of the following digital modulation techniques:

i) 8-Phase Shift Keying (8PSK). [6]

ii) 8-Quadrature Amplitude Modulation (8QAM) with rectangular constellation. [6]

(b) Determine the Quadrature PSK (QPSK) techniques contained in the above 8PSK and 8QAM showcasing their respective mathematical formulas. [3]

(c) If we employ QPSK, determine and justify the achievable bit rate to avoid intersymbol interference. [10]

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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

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

Laplace Transforms

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

End of question paper