



Beijing-Dublin International College



SPRING SEMESTER FINAL EXAMINATION – 2020/2021

UCD School of Electrical and Electronic Engineering

EEEN3006J Wireless Systems

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Time Allowed: 120 minutes

Instructions for Candidates

Answer any **THREE** questions. All questions carry equal marks.

BJUT Student ID: _____

UCD Student ID: _____

I have read and clearly understand the Examination Rules of both Beijing University of Technology and University College Dublin. I am aware of the Punishment for Violating the Rules of Beijing University of Technology and/or University College Dublin. I hereby promise to abide by the relevant rules and regulations by not giving or receiving any help during the exam. If caught violating the rules, I accept the punishment thereof.

Honesty Pledge: _____ **(Signature)**

Instructions for Invigilators

Non-programmable calculators are permitted.
No rough-work paper is to be provided for candidates.

Formulas

Vector calculus

$$\text{Div: } \vec{\nabla} \cdot \vec{A} = \left(\frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z} \right)$$

$$\text{Grad: } \vec{\nabla} \psi = \hat{i} \frac{\partial \psi}{\partial x} + \hat{j} \frac{\partial \psi}{\partial y} + \hat{k} \frac{\partial \psi}{\partial z}$$

$$\text{Curl: } \vec{\nabla} \times \vec{A} = \left(\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z} \right) \hat{i} + \left(\frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x} \right) \hat{j} + \left(\frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y} \right) \hat{k}$$

Useful constants

$$\text{Vacuum permeability: } \mu_0 = 4\pi \times 10^{-7} \text{ H}$$

$$\text{Vacuum permittivity: } \epsilon_0 = 8.85 \times 10^{-12} \text{ F}$$

$$\text{Boltzmann's constant: } k = 1.38064852 \times 10^{-23} \text{ m}^2 \text{ kg s}^{-2} \text{ K}^{-1}$$

Integral forms of Maxwell's Equations

$$\text{Gauss's Law for electric fields: } \oint_S \vec{E} \cdot \hat{n} da = \frac{q_{\text{enc}}}{\epsilon_0}$$

$$\text{Gauss's Law for magnetic fields: } \oint_S \vec{B} \cdot \hat{n} da = 0$$

$$\text{Farady's Law: } \oint_C \vec{E} \cdot d\vec{l} = -\frac{d}{dt} \int_S \vec{B} \cdot \hat{n} da \text{ or } \oint_C \vec{E} \cdot d\vec{l} = -\int_S \frac{\partial \vec{B}}{\partial t} \cdot \hat{n} da$$

$$\text{Ampere-Maxwell Law: } \oint_C \vec{B} \cdot d\vec{l} = \mu_0 \left(I_{\text{enc}} + \epsilon_0 \frac{d}{dt} \int_S \vec{E} \cdot \hat{n} da \right)$$

Derivative forms of Maxwell's Equations

$$\text{Gauss's Law for electric fields: } \vec{\nabla} \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

$$\text{Gauss's Law for magnetic fields: } \vec{\nabla} \cdot \vec{B} = 0$$

$$\text{Faraday's Law: } \vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\text{Ampere-Maxwell Law: } \vec{\nabla} \times \vec{B} = \mu_0 \left(\vec{J} + \epsilon_0 \frac{\partial \vec{E}}{\partial t} \right)$$

Some useful relationships

- Gauss's theorem: $\oint_S \vec{A} \cdot \hat{n} da = \oint_V (\vec{\nabla} \cdot \vec{A}) dV$
- Stokes' Theorem: $\oint_C \vec{A} \cdot d\vec{l} = \int_S (\vec{\nabla} \times \vec{A}) \cdot \hat{n} da$
- Curl of grad is always zero: $\vec{\nabla} \times \vec{\nabla} \psi = 0$
- Laplacian: $\vec{\nabla} \cdot \vec{\nabla} \psi = \nabla^2 \psi = \frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} + \frac{\partial^2 \psi}{\partial z^2}$
- Grad of div less Laplacian is curl of curl: $\vec{\nabla} (\vec{\nabla} \cdot \psi) - \nabla^2 \psi = \vec{\nabla} \times (\vec{\nabla} \times \psi)$

Link Design

$$\text{Friis' Transmission Equation: } P_{rx} = \frac{P_{tx} G_{tx} G_{rx} \lambda^2}{(4\pi)^2 r^2}$$

Useful trigonometric identities

$$\cos(a) \cos(b) = 0.5(\cos(a+b) + \cos(a-b))$$

Question 1:

- (a) A conducting sphere has an electrical charge density of $3.41 \times 10^{-11} \text{ C/m}^2$ and a radius of 4.2×10^{-3} and is centred within a surrounding cube with 0.5 m side length. What is the electric flux through one side of the cube?

(5 marks)

- (b) Find the divergence of a field given by $\vec{A} = \left(\frac{1}{r}\right) \hat{r}$ in spherical coordinates?

where:

$$\vec{\nabla} \circ \vec{A} = \frac{1}{r^2} \frac{\partial}{\partial r} (r^2 A_r) + \frac{1}{r \sin \theta} \frac{\partial}{\partial \theta} (A_\theta \sin \theta) + \frac{1}{r \sin \theta} \frac{\partial A_\phi}{\partial \phi}$$

(8 marks)

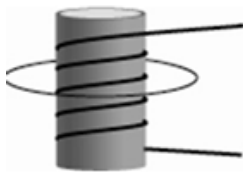
- (c) Find the displacement current produced between the plates of a discharging capacitor for which the charge varies as

$$Q(t) = Q_0 e^{-t/RC}$$

where Q_0 is the initial charge, C is the capacitance of the capacitor, and R is the resistance of the circuit through which the capacitor is discharging.

(10 marks)

- (d) A circular loop of wire surrounds a 5-turn solenoid of length .38 m and radius .1 m as shown in the figure. If the current in the solenoid increases linearly from 80 to 300 mA in 2 seconds, what is the maximum emf induced in the circular wire?



you can approximate the magnetic field as existing entirely **within** the solenoid and pointing upward along the solenoid axis, the magnitude of this field is:

$$|\vec{B}| = \frac{\mu_0 N I}{l}$$

(10 marks)

(33 marks)

Question 2:

(a) A cell phone is 950 m from a base station. The phone transmits at a frequency of 1.9 GHz and has a transmit power of 0.35 W. Its antenna has a gain of -14 dB. The base station antenna has a receiver gain of 30 dB. Receiver noise is 3 dBm. Calculate:

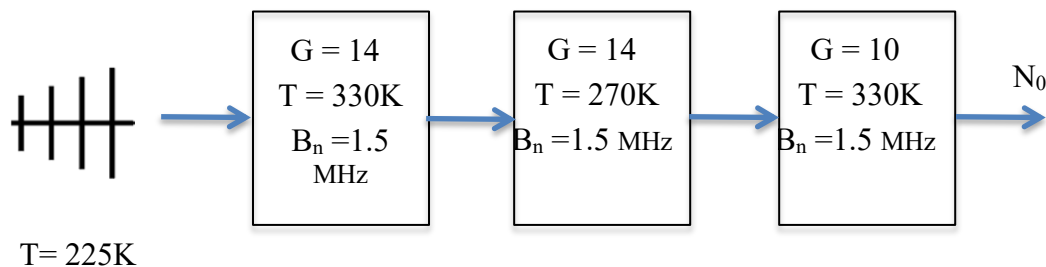
- The path loss, assuming free space propagation model
- The received SNR

(7 marks)

(b) An engineer wishes to set up a campus wide communication system between a cell tower and local radio receivers in the 863 MHz band. The tower can send signals at a maximum power of 25 dBm and has an antenna gain of 5 dB. The receivers have antenna gain of 1.4 dB and observe a noise floor of 5 nW. What is the maximum distance a receiver can travel from the tower if it required a SNR of 4.36 to successfully receive signals?

(7 marks)

(c) A signal from an antenna is passed through a matched system (as shown below) of bandwidth 1.5 MHz.



- What is the noise factor of the system?
- How can the components of the system be arranged for improved noise?
- What is the noise factor of the rearranged system?

(10 marks)

(d) Describe the main components in a radio system that introduce noise to a signal.

How do each components introduce noise? For each component, describe how noise can be reduced.

(5 marks)

(e) In your own words, describe how the introduction of noise negatively effects a radio system. You may refer to Shannon's theorem, modulation and encoding techniques or other concepts to explain your answer.

(4 marks)

(33 marks)

Question 3:

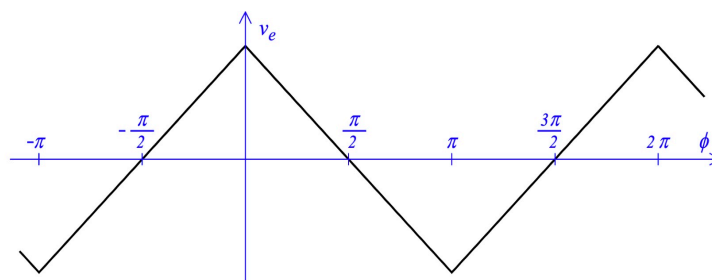
(a) Filter design:

- Discuss filter design with regard to roll-off, pass band and band stop attenuation?
- What tradeoffs are involved when designing a filter using electronic circuitry?
- Describe how a filter's centre frequency may be tuned in an electronic circuit.
- Compare a SAW filter and electronic filter with regard to roll-off, pass band and band stop attenuation.
- What is the main disadvantage of a SAW filter

(8 marks)

(b) Phase Locked Loop:

- Explain with the aid of a diagram the operation of a PLL.
- If a phase detector has a response characterised by the figure below and is in a stable state, what is the phase difference between the input signal and VCO output? Give an explanation for your answer.



(8 marks)

- (c) A fractional-N frequency synthesis unit must provide a stable sinusoidal output for a range of channels between 350 to 400 MHz with spacing of 125 kHz between channels. What are the values for f_{ref} , N , k and R for the channel with centre frequency at 386.25 MHz

(5 marks)

- (d) A signal centred at frequency $f_c = 886$ MHz and is mixed with a local oscillator at frequency $f_{LO} = 840$ MHz in an unbalanced mixer, what are the centre frequencies for the resulting fundamental, 2nd order and 3rd order InterModulation Products

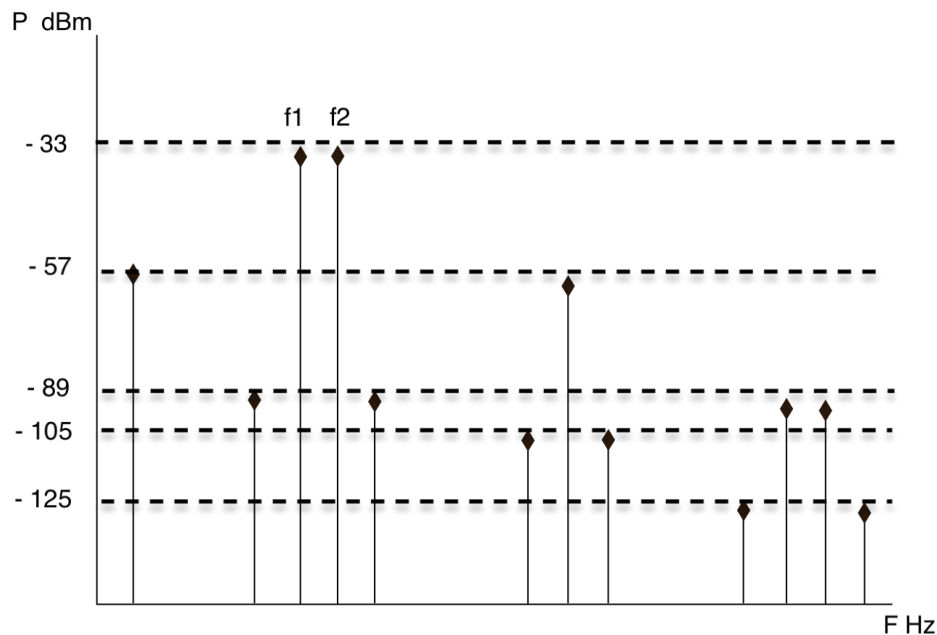
(6 marks)

- (e) The third order Intercept point can be estimated using the equation:

$$TOI = P_{\text{fundamental frequency}} + \frac{P_{\Delta}}{2}$$

Where P_{Δ} is the difference between the power of the fundamental frequency (P_F) and the adjacent 3rd order InterModulation Product (P_{IM3})

What is the TOI for the mixer with output as shown with input frequencies f_1 and f_2 :



(6 marks)

(33 marks)

Question 4:

(a) For the following radio system designs - Tuned Radio Frequency, Direct Conversion, Super-Hetrodyne:

- i Draw the receiver architecture
- ii Describe the operation of the receiver
- iii Discuss the strengths and weaknesses of the design
- iv Give an instance of where this design might be used

(10 marks)

(b) Explain the image frequency problem when receiving signals.

- i Show with the aid of a diagram the image rejecting frequency shift circuit. Explain how this circuit achieves image rejection.
- ii How might this problem be avoided without the need for an image rejecting circuit?

(10 marks)

(c) Explain the main issues arising when radio transmitters and receivers share the same antenna. What strategies are used to minimise these issues. How does the use of a given strategy effect the design of the transceiver and its components?

(8 marks)

(d) The objective of software radio is to replace the analogue components of the radio architecture with software processing that can be run to perform the same actions. Any signal must be converted from analogue to digital representation before software processing. Which components in the super-hetodyne architecture are suitable for software radio implementation? Explain your answer.

(5 marks)

(33 marks)