



An Coláiste Ollscoile, Baile Átha Cliath
University College Dublin

SPRING, 24/25 TRIMESTER EXAMINATIONS

**EEEN3006J
Wireless Systems**

Module Coordinator: Dr Declan Delaney

UCD Student Number

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Time Allowed: 120 minutes

Materials permitted:

Foreign language dictionary (hard copy)
Non-programmable or scientific calculator

Exam materials to be supplied:

12 Page Answer Booklets

Instructions to students:

Answer **Question 1, AND any 2** of the other **3 questions (Question 2, 3, 4)**. All question carry equal weight. If you attempt all questions your grade is computed from Question 1 and the best 2 of question 2, 3, 4. The marks given for each question part give an approximate indication of the relative weight to that part of the question.

Question 1:

Answer all the following parts, they all carry equal marks.

- a) A transmitter is designed to transmit a signal of bandwidth 1 MHz, at any transmit (centre) frequency in the range 640 MHz to 678 MHz. The modulator operates at a fixed (centre) frequency. Its output is shifted to the transmit frequency using a mixer, adjustable oscillator and band-pass filter as shown. The filter passband covers the range of transmit (centre) frequencies, plus an extra 1 MHz on each side. The filter stopbands begin 17 MHz (shown as s in the diagram) away from the passband edges. What is the minimum frequency at which the modulator can operate? You may assume that the mixer is an ideal multiplier, with no leakage. Give your answer in MHz, rounded to one decimal place.

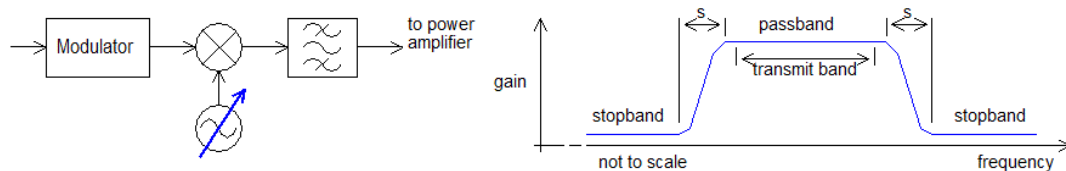


Figure 1: Block diagram and image of frequency spectrum to be used in question 1 a).

[25%]

- b) GSM 450 operates in the frequency range between 450.6 MHz – 457.6 MHz (with first channel centred on 450.6 MHz, and last used channel centred on 457.6 MHz), with each channel having a bandwidth of 200 kHz. A designer uses a PLL design to synthesise the required frequencies. They have a choices of two frequencies for the reference frequency (f_{ref}):
 $f_{\text{ref}} = 10 \text{ MHz}$
 $f_{\text{ref}} = 16 \text{ MHz}$

Analyse and compare both solutions with respect to their influence on: loop filter dynamics and phase noise, and spur effects.

Which solution would you pick?

Note: Spur frequencies occur at the modulo of the divider ratio (R) and typically appear at offsets to the channel frequency equal to the reference frequency divided by R :

$$f_{\text{spurs}} = f_{\text{channel}} \pm n * \frac{f_{\text{ref}}}{R}, \quad n = 1, 2, 3, 4 \dots$$

[25%]

- c) The power amplifier of a radio has a small-signal gain of 18 dB and its third-order intercept point is at an input power of 4 dBW. The amplifier is followed by a low-pass filter with corner frequency 900 MHz, passband loss 0.5 dB and attenuation of at least 60 dB at frequencies above 940 MHz. The transmitter output should be the sum of two sinusoidal signals with equal power, at frequencies of 800 MHz and 850 MHz. Any other signal (Inter-Modulation Products, harmonics, other) at the filter output must not exceed 5 mW? What is the maximum allowable power of the signals at the filter output?

[25%]

- d) An amplifier is modelled using a 5th order polynomial. If the amplifier model has on its input a signal with frequencies at 450 MHz and 435 MHz ($v_{in} = \cos(2 * \pi * 435 \times 10^6 * t) + \cos(2 * \pi * 450 \times 10^6 * t)$) what are the expected **frequencies** present in the output of the amplifier where:

$$V_{out} = \sum_n^5 b_n v_{in}^n$$

Answers should be given in MHz.

[25%]

Question 2

Figure 2 shows the block diagram of a receiver design for processing signals of bandwidth 350 kHz. All analogue inputs and outputs are matched to 50 Ω . The receiver is expected to receive signals between -95 dBm and -40 dBm. In each part of this question, show how you arrive at your answers.

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

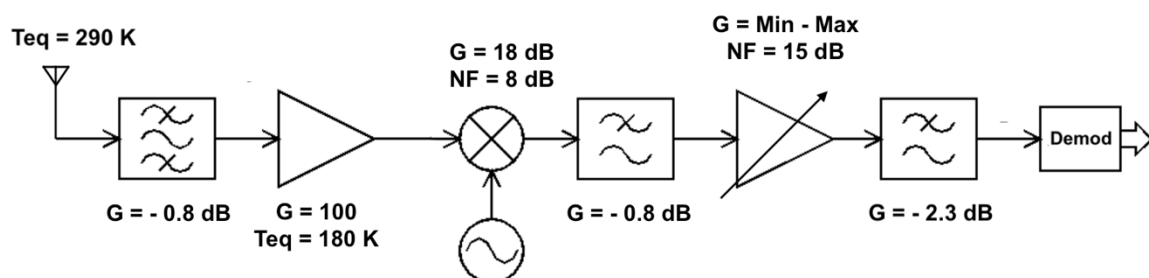


Figure 2: Receiver architecture for use in question 2.

- a) Calculate the equivalent noise temperature of the receiver, over the full bandwidth of the received signal. You may assume that the gain of the baseband adjustable amplifier is very large.

[40%]

- b) The receiver is connected to an antenna with noise temperature 290 K. Calculate the minimum SNR expected at the demodulator. (If you have not answered part a) you may use 290 K for the temperature equivalent of the receiver network.)

[30%]

- c) For the digital demodulator to work correctly the RMS voltage of the wanted input signals entering the demodulator ADC must be between 20 mV and 2 V. What are the Min and Max gain allowed in the baseband adjustable amplifier which satisfies this constraint?

[30%]

Question 3

- a) A cell phone is 950 m from a base station. It uses a communications channel at a centre frequency of 1.9 GHz and has a transmit power of 0.35 W. Its antenna has a gain of -14 dBi in the direction of the receiver. The base station antenna has a receiver gain of 30 dBi. Receiver noise is -76.2 dBm.

Calculate:

- The path loss, assuming a free space propagation model
- The received Signal to Noise Ratio

[40 %]

- b) A microwave transmitter is placed on a hill which transmits a signal at 3.5 GHz towards nearby city, at a distance of 50 Km. A receiver uses an antenna with effective aperture $.6 \text{ m}^2$ to receive the signal and needs a receive power of at least -60 dBm for acceptable operation.

- What EIRP is needed at the transmitter microwave if a margin of 8 dB is required for fading in bad weather? Give your answer in decibels rounded to one decimal place.
- A new receiver antenna is due to be installed that achieves a 5.5 dB over the current design. If the only change made by the new antenna is to the aperture, what is the size of the aperture of the new dish.

[60 %]

Question 4

- a) Design a receiver so that it can receive signals at frequencies in the range 1.4 GHz to 1.9 GHz. The signal bandwidth is 400 kHz, and the demodulation will be performed at a non-zero frequency, with channel selection performed prior to the demodulator. Design the architecture (not including the demodulator), without using any filter of bandwidth less than 0.2% of its centre frequency. Give reasons for your design decisions. Draw a block diagram showing your design. Specify the centre frequency and bandwidth of the filters used and the frequency or frequency range of any oscillator used.

[80%]

- b) A transceiver uses a shared antenna to send and receive signals and uses Frequency Division Duplexing to separate send and receive channels. The Low Noise Amplifier (LNA) in the receiver side can be modelled using a 3rd order polynomial with the coefficients: $b_0 = 0$, $b_1 = 12$, $b_2 = 0$, $b_3 = -1.2$. The RF filter provides a passband gain of -3 dB and a stopband gain of -30 dB. If the in-band received signal has a power of -77.9 dBm, what transmit signal (out of band) power will induce gain blocking in the LNA? All analogue inputs and outputs are matched to 50 Ω .

[20%]

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