ENGINEERING TRIPOS PART IIA

Tuesday 1 May 2007 2.30 to 4.00

Module 3B1

RADIO FREQUENCY ELECTRONICS

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

STATIONERY REQUIREMENTS

Single-sided script paper

SPECIAL REQUIREMENTS

Engineering Data Book

CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

1 A remote weather station is to transmit wind speed and direction data via a 434 MHz radio link to a base station receiver some distance away. The transmitter is based on a Colpitts oscillator circuit and the wind speed and direction data are to be modulated onto the carrier wave using AM and FM respectively.

(a) Draw a circuit diagram for a Colpitts oscillator and explain the function of each of the components used. [25%]

(b) Design a Colpitts oscillator circuit to meet the following specification:-

Nominal frequency:	434 MHz
Output Power:	2 mW into a 100 Ω load
Supply voltage:	3.3 Vdc

You should use tank circuit capacitors of 220 pF and give the value of all other components used. You may assume that a suitable transistor is available. [40%]

(c) The wind speed sensor, which is based on spinning blades, produces a 1 Vpp sine-wave output at a frequency of around 10 – 100 Hz. The wind direction sensor is based on a moving vane, producing an output which may be represented electrically by a variable capacitor of value 1 – 5 pF.

What changes and/or additions to the basic oscillator circuit are required in order to achieve a frequency modulation range of 2 MHz, related to the wind direction, and an amplitude modulation of around 50%, related to the wind speed ? Give the values of all components used. [35%]

State all assumptions and approximations made.

2 An RF amplifier is required as part of a radio data link for a remote weather station, to boost the carrier signal from an RF oscillator by 20 dB before it is fed to the antenna. The nominal frequency of operation is 434 MHz.

(a) Draw a circuit diagram for a single stage RF transistor amplifier and briefly describe the function of each of the components shown. [25%]

(b) Design an RF amplifier circuit to provide 20 dB of power gain with input and output impedances matched to the source and load impedances of 100 Ω. The amplifier should operate from a 20 Vdc supply and be able to provide up to 200 mW output power. You may assume that a suitable transistor with $h_{fe} = 250$ is available. [40%]

(c) In order to be able to operate two weather stations simultaneously, an engineer wonders whether one of the stations can be set to operate on a higher frequency band by doubling the carrier frequency to 868 MHz. If the transistor has the following properties: $h_{fe} = 250$, $f_t = 18$ GHz, $c_{cb} = 0.15$ pF, $c_{oe} = 0.10$ pF; would the RF amplifier designed in part (b) be able to provide sufficient gain at this higher frequency? [35%]

State all assumptions and approximations made.

3 The radio receiver for 2 analogue data signals transmitted at 434 MHz from a weather station, using both AM and FM schemes, operates on the Superheterodyne principle with an Intermediate Frequency (IF) of 20 MHz at around 1 Vpp amplitude.

(a) Draw a schematic system diagram for a Superhet receiver and briefly describe how the receiver operates. How is it tuned to the desired carrier frequency and how can the system cope with a wide range of received signal strengths ? [25%]

(b) Design a demodulation circuit using a pair of 2-pole VCVS filters and other circuitry to recover the signal encoded by FM on the carrier, assuming the maximum FM range to be around 2 MHz and the signal bandwidth to be < 1 kHz. The output signal should be around 2 Vpp. A VCVS filter design table is given below. [45%]

(c) Design an analogue demodulation circuit to recover the signal encoded by AM on the carrier, assuming the maximum depth of modulation to be around 50% and the signal bandwidth to be < 100 Hz. The output signal should be around 2 Vpp. [20%]

(d) If the IF filter used does not have flat response over its pass-band, but instead behaves like an LC resonant circuit with a fairly low Q-factor (≈ 5) to achieve the required bandwidth, how will this tend to affect the operation of the receiver ? [10%]

Give the values of components used and state all assumptions and approximations made.

<u>VCVS 2-pole filter design table</u>

Bessel		Butterworth		Chebyshev 0.5 dB	
f_n	A	f_n	A	f_n	A
1.274	1.268	1.000	1.586	1.231	1.842

4 A 200 mW radio carrier signal at 434 MHz is transmitted from a remote weather station using an antenna with a $Gain = 3$.

(a) If the receiving base station is at a distance of 10 km from the remote transmitter and has an antenna with a $Gain = 50$, what amplitude of signal will be detected across the receiving antenna with a matched load of 100 Ω ? [35%]

(b) The transmitting station uses a rectangular microstrip patch antenna fabricated on a plastic circuit board. If the board insulation is 1.60 mm thick with a relative permittivity $\varepsilon_r = 2.5$, what should be the length of this patch antenna ? Also, what width of track for the feed line is required to realise a characteristic impedance of 100 Ω on this circuit board ? [35%]

(c) It turns out that the feed-point for a particular patch antenna has an input impedance of 73 + j50 Ω instead of the intended 100 Ω. Design an LC matching circuit, using a series capacitor and a parallel inductor, to convert the antenna impedance to 100 Ω.

How would the impedance at the feed-point of a rectangular patch antenna change, in general terms, as the position of the feed-point is varied from being near the centre to being closer to the end of the patch ? [30%]

The matching circuit may be designed either by calculation or by using a Smith Chart. State all assumptions and approximations made.

END OF PAPER

Chart for question 4; to be detached and handed in with script.