UNIVERSITY OF CAMBRIDGE

ENGINEERING TRIPOS PART IIA

Tuesday 27 April 2004 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.*

Attachment:

Chart for question 4, to be submitted with the solution.

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

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1 (a) Sketch a circuit for a Colpitts RF oscillator and briefly explain the function of each of the components. [25%]

(b) Design a Colpitts oscillator to produce a 3 MHz sine-wave output, at a power level of at least 3 dBm into a 1 kΩ load. The circuit should operate with a supply voltage of +10 V . Give the values of all components used in your design. You may assume that a suitable NPN transistor is available with $h_{fe} = 200$. [50%]

(c) It is desired to send digital data by switching the frequency of the oscillator between 2.5 MHz and 3 MHz, as part of a Frequency Shift Keyed (FSK) system. Add some extra components to the circuit designed in part (b) to allow frequency selection of the oscillator in response to a 0 – 5 V digital signal.

State all assumptions and approximations made. [25%]

2 (a) Sketch the circuit for a 2-pole low-pass VCVS filter and briefly describe the modifications required to change this to a high-pass filter. [20%]

(b) A Frequency Shift Keyed (FSK) digital signal on a sinusoidal carrier of amplitude 0.5 V , alternating between 2.5 MHz and 3 MHz , is to be demodulated using a pair of VCVS filters and other circuitry.

(i) Sketch a block diagram to show how the filters and other circuit functions should be arranged to recover the digital signal from the carrier. [25%]

(ii) With reference to Table 1 below, design suitable circuits to realise the functional blocks required. Justify your choice of filter type and give the values of all components used. [40%]

(iii) Estimate the maximum digital data rate recoverable using your circuit. State any assumptions and approximations made. [15%]

Table 1

2-pole VCVS filter design table

Filter type	f_n	A
Bessel	1.274	1.268
Butterworth	1.000	1.586
Chebyshev	1.231	1.842

3 (a) Briefly explain the following terms when applied to radio antenna characteristics:

Radiation Resistance;

Radiation Efficiency;

Gain;

Effective Aperture;

Skin Depth. [20%]

(b) Estimate the *Radiation Resistance* of a short dipole antenna with each arm of length 20 cm , when operating at a frequency of 40 MHz . Assume a linear tapered current distribution along each arm. [15%]

(c) If the antenna is driven from a 10 $V_{p\text{-}p}$, 75 Ω impedance source calculate the total power radiated and the power received by an identical antenna situated 1 km away, when positioned in its optimum orientation. You may assume that any reactive components of the antenna impedance have been cancelled. State any other assumptions and approximations made. [45%]

(d) Estimate the *Radiation Efficiency* of the antenna when operating at 40 MHz if it is made from 1 mm diameter, non-magnetic stainless steel (with a conductivity of 1.2×10^6 S m^{-1}). [20%]

Note: For an **ideal** dipole antenna of length Δz and operating wavelength λ the *Gain* = 1.5 and the *Radiation Resistance* = $80\,\pi^2\,(\Delta z/\lambda)^2\ \Omega$.

4 (a) Design an impedance matching circuit to match an antenna of impedance $250 + j100\ \Omega$ to a transmitter circuit of output impedance $50\ \Omega$, for an operating frequency of 200 MHz. Give the values of all components used. [20%]

(b) A transmitter circuit is to be constructed in microstrip on a fibre-glass printed circuit board (PCB) with a relative permittivity ε_r of 4.3 and a thickness of 1.6 mm. Determine the width of track required for the microstrip characteristic impedance to be $50\ \Omega$, stating any assumptions and approximations made. [40%]

(c) A power amplifier has an input scattering parameter $S_{11} = 0.68\angle -85°$. Plot this point on the Smith Chart provided overleaf and design a matching circuit, employing a length of microstrip transmission line as specified in part (b) and a series capacitor, to match the input to $50\ \Omega$ at a frequency of 200 MHz. Give the capacitor value and microstrip dimensions employed and plot the matching path on the Smith Chart.

Detach the Smith Chart from the question paper and hand it in with your answer. [40%]

END OF PAPER