ENGINEERING TRIPOS PART IIA

Tuesday 27 April 2010 2.30 to 4.00pm

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 detached and submitted with the solution

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

Final version

1. (a) Describe what is meant by the term *image rejection* when applied to the design of an amplitude modulated (AM) superheterodyne (superhet) radio receiver. [20%]

If an AM superhet radio has a local oscillator (LO) frequency of 1.5 MHz and an intermediate frequency (IF) of 455 kHz, what is the frequency of the tuned radio station? What is the image frequency? [10%]

(b) Explain, with the aid of a block diagram, the way in which an AM superhet radio receiver tunes different radio stations. Define the operation of each element in the system. Describe how the design can be modified to include a simple form of image rejection in this tuning process. [30%]

Describe the importance of LO and radio frequency filter tracking in the modified superhet receiver and how it can be achieved. [10%]

(c) If the superhet radio was designed to be frequency modulated (FM) instead of AM, show how a phase locked loop (PLL) can be used to demodulate the intermediate frequency signal. [30%]

2 (a) Given a circuit contains elements of gain and feedback, describe the conditions under which oscillation will occur. How is an oscillator designed using these principles so that it only generates one frequency component? [20%]

(b) Sketch the layout of a Colpitts oscillator and briefly explain the function of each of the circuit elements. [20%]

(c) Given that $V_{CC} = 5$ V, and an NPN transistor has specifications of $h_{fe} = 200$, $V_{be} = 0.75$ V, $f_T = 250$ MHz, design a Colpitts oscillator to deliver a 1.5 MHz sinusoidal wave at a power level of 2 dBm into a 400 ohm load. You may assume a 15 μH inductor is available for your design. [45%]

(d) The circuit designed in (c) was built, but the output was found to contain a significant amount of the 3rd harmonic frequency component. How could the circuit be modified to minimise this distortion? [15%]

3 (a) Sketch a 2 pole low pass voltage controlled voltage source (VCVS) filter. Show how this circuit can generate a filter functionality of the form:

$$\left|\frac{V_0}{V_i}\right| = A\left[1+B\left(\frac{\omega}{\omega_n}\right)^2+\left(\frac{\omega}{\omega_n}\right)^4\right]^{-\frac{1}{2}}$$

Define all of the terms in your sketch and derivation. [50%]

(b) A quadrature amplitude modulation (QAM) modem has a frequency pass band from 150 Hz to 3.4 kHz but cannot tolerate any variation of amplitude across this passband. Design a suitable VCVS bandpass filter using the data in Table 1, given that there are 4 operational amplifiers available for the design. [40%]

(c) What techniques might be employed to further eliminate variations in the amplitude across the passband of the VCVS filter? [10%]

n	Bessel		Butterworth		Chebyshev	(0.5dB)
	f_n	A	f_n	A	f_n	A
2	1.274	1.268	1	1.586	1.231	1.842
4	1.432	1.084	1	1.152	0.597	1.582
	1.606	1.759	1	2.235	1.031	2.660
6	1.607	1.040	1	1.068	0.396	1.537
	1.692	1.364	1	1.586	0.768	2.448
	1.908	2.023	1	2.483	1.011	2.846

Table 1

4 (a) Briefly describe two ways in which a Smith chart can be used to calculate the length of a transmission line required to match two impedances at radio frequencies. [20%]

(b) Derive an expression for the characteristic impedance for the microstrip line shown in Fig. 1. State any approximations made. [30%]

(c) A short length of microstrip transmission line is to be used to match a 200 Ω source to a 75 Ω patch antenna operating at a frequency of 1.8 GHz. Use a Smith chart to calculate the required series capacitance, the length of 0.5 mm wide copper track and the required thickness of the microstrip using a printed circuit board with dielectric constant $\varepsilon_r = 3.7$. Comment on the suitability of this matching. [40%]

How would the design change if the microstrip was also required to supply dc power to the antenna? [10%]

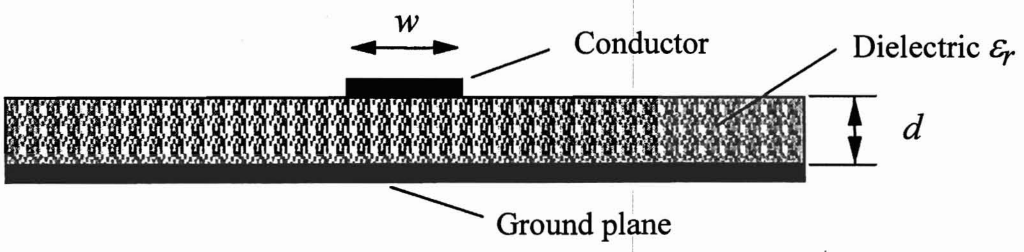

Fig 1.

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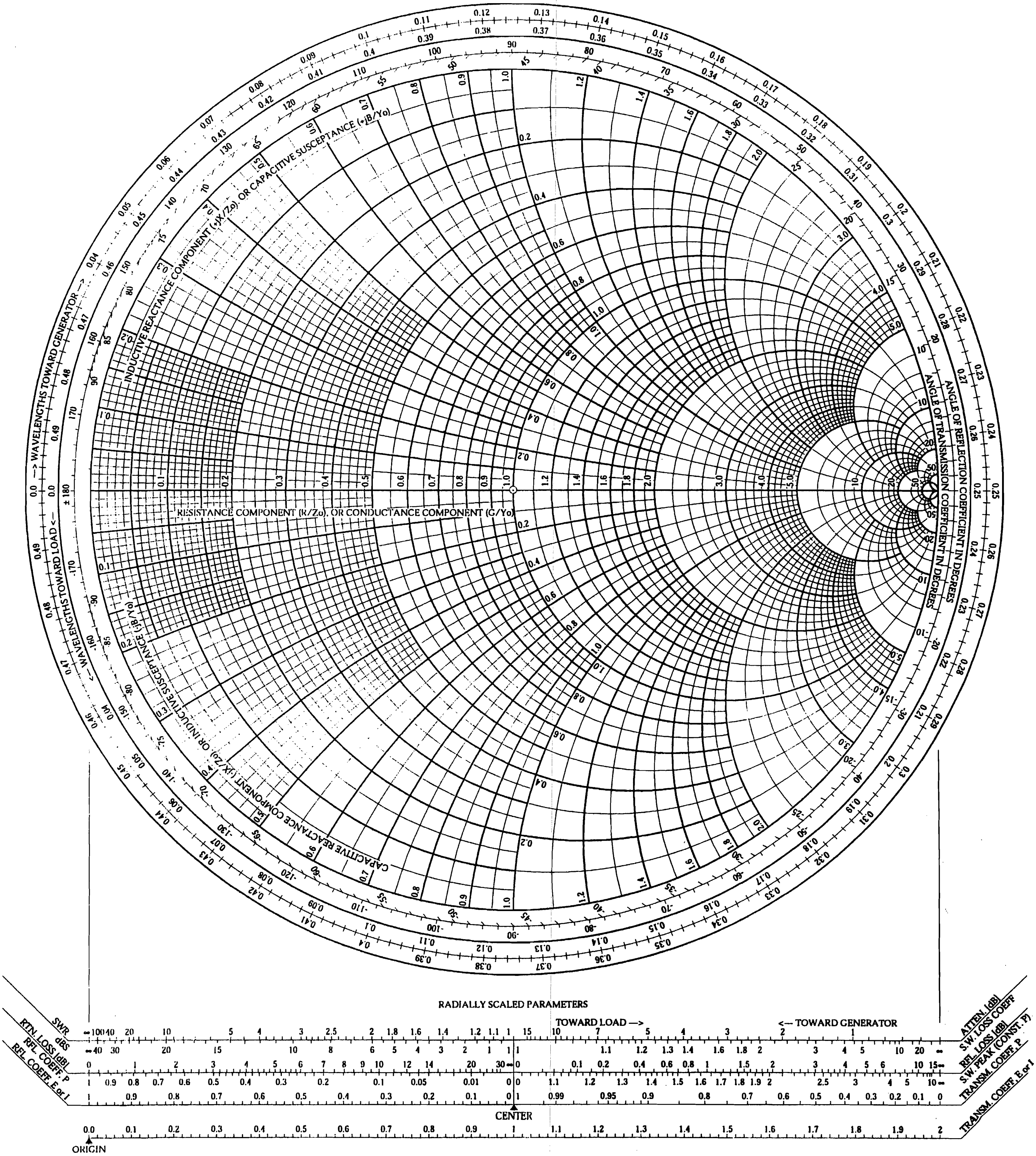
Final version

Chart for question 4; to be handed in with script



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