2207/303
COMMUNICATION AND NAVIGATION SYSTEMS
Oct./Nov. 2019
Time: 3 hours

THE KENYA NATIONAL EXAMINATIONS COUNCIL

DIPLOMA IN AERONAUTICAL ENGINEERING (AVIONICS) (COMMUNICATION AND NAVIGATION OPTION)

COMMUNICATION AND NAVIGATION SYSTEMS

3 hours

INSTRUCTIONS TO CANDIDATES

You should have the following for this examination:
Answer booklet;
Mathematical tables/non-programmable scientific calculators;
Drawing instruments.
*This paper consists of **EIGHT** questions.*
*Answer any **FIVE** of the **EIGHT** questions in the answer booklet provided.*
All questions carry equal marks.
Maximum marks for each part of a question are as shown.
Candidates should answer the questions in English.

Take: Free space wave velocity, $c = 3 \times 10^8$ m/s
Impedance of free space $Z_0 = 377\ \Omega$;
Radius of the Earth, R = 6400 km

This paper consists of 6 printed pages.

Candidates should check the question paper to ascertain that all pages are printed as indicated and that no questions are missing.

Turn over

1. (a) (i) Draw a labelled block diagram of an independent sideband transmitter and describe its operation.

(ii) State **two** merits of FM radio transmitters.

(10 marks)

(b) A DSB-AM radio transmitter has a carrier power of 10 kW and transmits 12 kW of power when modulated by a single-sine wave signal. Determine the:

(i) modulation index;
(ii) upper sideband power.

(4 marks)

(c) Figure 1 shows a circuit diagram of a Colpitts oscillator used in a radio transmitter.

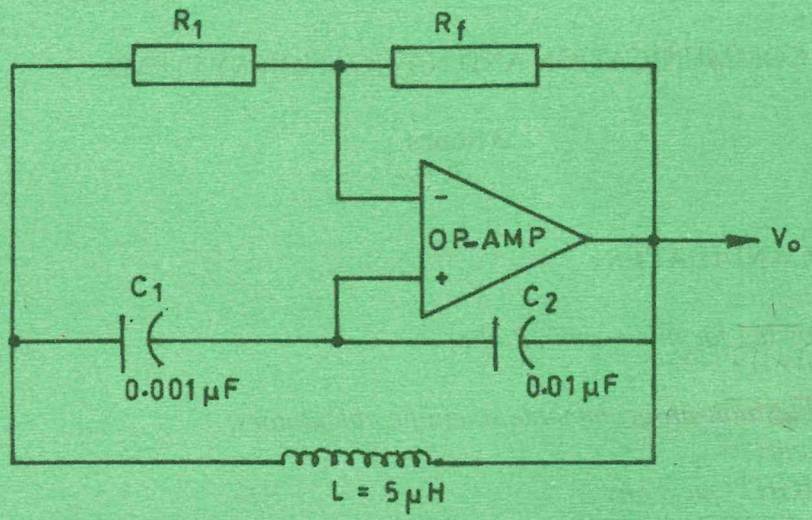

Fig 1

Determine the:

(i) frequency of oscillation;
(ii) minimum gain required for oscillation.

(6 marks)

2. (a) Define each of the following with respect to satellite communication:

(i) spacecraft;
(ii) geostationary orbit;
(iii) effective isotropic radiated power (EIRP).

(3 marks)

(b) Explain **three** factors considered when designing a satellite earth station.

(6 marks)

(c) A satellite is placed on a circular orbit above the earth and it takes 24 hours to encircle the earth. If the satellite velocity is 11,040 km/hr determine the:

(i) satellite velocity in m/s;
(ii) height of the satellite above the earth.

(7 marks)

(d) State:

(i) **two** disadvantages of satellite over optical fibre cable in signal communication;

(ii) **two** reasons for use of microwave frequencies in satellite communication.

(4 marks)

3. (a) Define each of the following with respect to antennas:

(i) polarization;
(ii) directive gain;
(iii) beam width.

(3 marks)

(b) An antenna array, consists of two-point sources spaced 'd' metres apart on the horizontal plane. It is energised by a field strength 'E' and carry currents of the same phase.

(i) With the aid of a vector diagram, show that the expression for the resultant field strength,

$$E_T = 2E_0 \text{Cos}\left(\frac{\pi d}{\lambda}\cos\theta\right) \text{V/m}$$

where E_0 = Electric field from each point source;
λ = signal wavelength, m

(ii) using the expression in b(i), sketch the radiation pattern for the array, for $d = \lambda/2$.

(10 marks)

(c) (i) With the aid of a diagram, describe the offset method of feeding a parabolic microwave antenna.

(ii) State **two** merits of the method in c(i).

(7 marks)

4. (a) (i) Outline the principles of operation of a distance measuring equipment (DME) in aircraft radio navigation.

(ii) Describe each of the following with respect to DME:

(I) slant-range error;
(II) scanning DME.

(8 marks)

(b) A radar transmitter has a peak power of 400 kW, pulse repetition frequency (PRF) of 2,500 pps and pulse width of 0.7 μS. Determine the:

(i) duty cycle;
(ii) average transmitted power;
(iii) maximum un-ambigous range.

(6 marks)

(c) Draw a labelled block diagram of a pulsed radar transmitter-receiver and state the function of each block. (6 marks)

5. (a) With the aid of a labelled diagram, describe the operation of a photo-diode detector. (6 marks)

(b) An optical fibre has a core of refractive index of 1.50 and a cladding of refractive index 1.46. Determine the:

(i) numerical aperture;
(ii) acceptance angle;
(iii) critical angle.

(6 marks)

(c) (i) With the aid of a labelled ray-diagram, describe the propagation of light through a graded-index multi-mode optical fibre cable.

(ii) State **two** characteristics of stepped-index monomode fibre.

(8 marks)

6. (a) (i) State **two** advantages of waveguides over coaxial cables in transmitting microwave signals.

(ii) Define each of the following with respect to waveguides:

(I) guide wavelength;
(II) cut-off wavelength.

(4 marks)

(b) With the aid of a diagram describe the operation of a cavity resonator at microwave frequencies. (6 marks)

(c) A circular waveguide has an internal radius of 2.25 cm and propagates a 10 GHz signal in the $TE_{1,1}$ mode:
Determine the:

(i) cut-off wavelength;
(ii) guide wavelength;
(iii) group velocity;
(iv) characteristic impendance.

(**Note:** Take the solution of Bessel function (Kr) = 1.84 for the $TE_{1,1}$ mode) (10 marks)

7. (a) (i) Define each of the following with respect to pulse code modulation (PCM);

(ii) Companding;

(iii) Nyquist rate.

(2 marks)

(b) A PCM system uses n-bits and a step size of Δ. Show that the mean square of the quantisation noise voltage, V^2_n, is given by:

$$V^2_n = \frac{\Delta^2}{12}$$

(8 marks)

(c) A PCM system has the following parameters:

maximum analog input signal frequency = 15 kHz
maximum decoded voltage at the receiver = ±5 V
minimum dynamic range = 40 dB

Determine the:

(i) minimum sampling rate;
(ii) minimum number of bits;
(iii) resolution.

(8 marks)

(d) State **two** merits of digital transmission systems. (2 marks)

8. (a) An RF carrier signal with a frequency of 512 kHz is received on a 75 Ω antenna of a superheterodyne receiver. The receiver has an IF of 455 kHz. The front-end amplifier has a gain of 14 dB, the mixer conversion loss is 7 dB and the IF filter has an insertion loss of 3 dB.
The IF amplifier has two stages, each with a gain of 25 dB. The demodulator requires a carrier power of at least 2.5 dBm.

(i) determine the:

(I) local oscillator (L.O) frequency in Hertz.
(II) Image frequency, in Hertz;

(ii) draw labelled block diagram of the receiver, showing the powers in dBm at the input of each stage.

(iii) determine the input voltage of the received carrier signal that can be demodulated.

(14 marks)

(b) With the aid of a circuit diagram, explain the operation of an AM radio diode-envelope detector and sketch the output waveform.

(6 marks)

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