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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	SATELLITE COMMUNICATION AND NAVIGATION
COURSE CODE	:	BEJ 41403
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS. 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.** 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

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Q1 (a) Describe the forces affecting a satellite in orbit.

(4 marks)

(b) You are given the task of choosing the most suitable orbit for an earth observation satellite. Identify the orbit and give justification for your choice.

(4 marks)

(c) Global Positioning Satellite (GPS) is a system that uses a constellation of satellites to fix a position which can then be used for navigation.

(i) Briefly describe the process of obtaining a position fix by using a GPS system.

(5 marks)

(ii) Explain **THREE (3)** factors that can affect the accuracy of the GPS system.

(3 marks)

(iii) Justify the choice of orbit for the GPS system.

(4 marks)

Q2 (a) Differentiate between geosynchronous and geostationary orbit.

(4 marks)

(b) The Two Line Element (TLE) data set for MEASAT 3B satellite is given below:

```
MEASAT-3B
1 40147U 14054B   22347.77323225 -.00000223  00000+0  00000+0 0  9995
2 40147   0.0496  52.8353 0001316 299.4578 100.0081  1.00271956 30327
```

(i) Determine the launch year and the epoch date and time.

(4 marks)

(ii) Extract the Keplerian elements from the TLE set and calculate its true anomaly. Assume the satellite's orbit is perfectly circular.

(9 marks)

(c) An Astro TV subscriber wants to watch TV programmes broadcasted by the MEASAT 3B (longitude 91.5° E) at his home in Parit Raja, Batu Pahat (latitude 1.8635°, longitude 103.1089, elevation 7 m). For that to happen, he needs to align his parabolic dish antenna to the exact satellite location in space. From the data obtained in **Q2(b)**, determine the following parameters.

(i) the slant range, d,

(3 marks)

(ii) azimuth angle, A_z,

(3 marks)

(iii) elevation angle, θ of the earth station, and

(2 marks)

Q3 (a) (i) Analyse the rain attenuation for a user for a circularly polarized signal if the rain height is 5 km with a reduction factor, $p = 0.01\%$ for a point rate of 100 mm/h. The antenna elevation $\theta = 76°$.

(7 marks)

(iii) Examine techniques that can be implemented by the service provider to mitigate the effect of rain attenuation.

(3 marks)

(b) Discuss the cause of depolarization and its effect on satellite's signal.

(5 marks)

Q4 (a) The MEASAT 3B satellite receives an uplink broadcasting signal at 14 GHz from a ground station located in Bukit Jalil, Malaysia. The ground station has an antenna with a gain of 60 dB and the distance between the ground station and the satellite is 35,776.601 km. The antenna has an input power of 140 W and other transmission losses are estimated at 12 dB. The satellite's effective isotropic radiated power (EIRP) is given in **Figure Q4.**

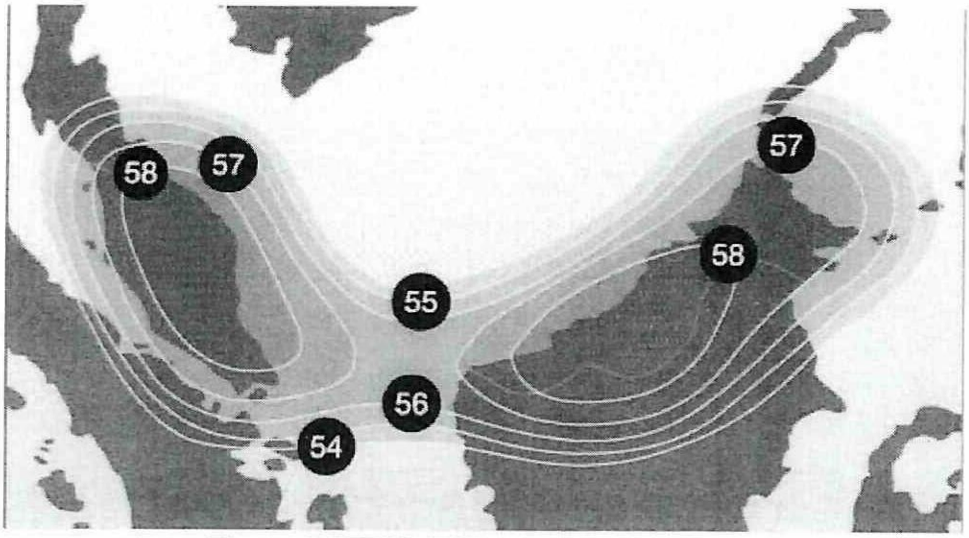

Figure Q4 EIRP FOR MEASAT 3B

(i) Calculate the flux density at the input of the satellite antenna.

(3 marks)

(ii) If the satellite antenna has a gain of 20 dB for both transmit and receive modes, calculate the amount of gain the travelling wave tube amplifier (TWTA) must deliver to produce the stated satellite's EIRP.

(5 marks)

(b) A ground station in Parit Raja, Malaysia is equipped with a 60 cm in diameter parabolic dish antenna with an efficiency of 55%. The station receives a Broadcasting Satellite Service (BSS) at Ku-band frequency of 12 GHz from the MEASAT 3B satellite (longitude 91.5° E). The effective isotropic radiated power (EIRP) is given in **Figure Q4.**

(i) Calculate the gain of the receiver's parabolic dish antenna in dB.

(3 marks)

(ii) Analyse the carrier-to-noise density ratio (C/N_0) at the dish interface. Assume $T_s = 400\ K$, the antenna pointing loss of 0.5 dB, the atmospheric loss is 0.2 dB and a rain fade of 30 dB is predicted for 99.99% availability.

(5 marks)

(iii) Calculate the receiver's G/T ratio. Explain the significance of G/T ratio in a satellite communication link.

(5 marks)

(c) Scintillation is one impairment that happens to signal travelling from a satellite to a ground station. Discuss the cause of scintillation and the effect it has on critical applications.

(4 marks)

Q5 (a) Explain the advantages of Time Division Multiple Access in satellite communication

(4 marks)

(b) In an FDMA scheme, the carriers utilize equal powers and equal bandwidths. The bandwidth for each channel is 5 MHz and the transponder bandwidth is 36 MHz. The saturation EIRP for the downlink is 34 dBW, and an output backoff of 6 dB is employed. The downlink losses are 201 dB, and the destination earth station has a G/T ratio of 35 dBK^{-1}. Determine;

(i) the carrier-to-noise ratio, $[C/N]$ assuming this is set by a single carrier operation.

(3 marks)

(ii) the number of carriers which can access the system and state, with reasons, whether the system is power-limited or bandwidth limited.

(3 marks)

(c) The code waveform in a CDMA system spreads the carrier over the full 36 MHz bandwidth of a transponder channel, and the roll-off factor for the filtering is 0.4. The information bit rate is 64 kb/s, and the system uses the binary phase shift keying (BPSK) modulation technique. Calculate the processing gain in decibels.

(5 marks)

- END OF QUESTIONS -

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CONSTANTS

Earth equatorial radius, $R_e = 6378.137$ km
Earth polar radius, $R_p = 6356.752$ km
Earth mean radius, $R_E = 6371.009$ km
Gravitational parameter, $\mu = 3.986 \times 10^{14}$ $m^3 s^{-2}$
Earth rotation rate around the Sun = $0.9856°$ /day
Boltzmann's constant, $k = 1.3806 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}
Speed of light, $c = 3 \times 10^8$ ms^{-1}

FORMULAE

Orbital Formulae

For near circular orbit where the eccentricity is small, an approximation for true anomaly ν directly in terms of M (in radians) is

$$\nu \cong M + 2e \sin M + \frac{5}{4} e^2 \sin 2M$$

Radius, velocity and period

$$r = \frac{a(1-e^2)}{1 + e\cos\nu} \qquad v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)} \qquad T = 2\pi\sqrt{\frac{a^3}{\mu}}$$

Coordinate Transformation

$$\mathbf{r} = (r\cos\nu)\mathbf{P} + (r\sin\nu)\mathbf{Q}$$

$$\begin{bmatrix} r_I \\ r_J \\ r_K \end{bmatrix} = \widetilde{\mathbf{R}} \begin{bmatrix} r_P \\ r_Q \end{bmatrix}$$

$$\widetilde{\mathbf{R}} = \begin{bmatrix} (\cos\Omega\cos\omega - \sin\Omega\sin\omega\cos i) & (-\cos\Omega\sin\omega - \sin\Omega\cos\omega\cos i) \\ (\sin\Omega\cos\omega + \cos\Omega\sin\omega\cos i) & (-\sin\Omega\sin\omega + \cos\Omega\cos\omega\cos i) \\ (\sin\omega\sin i) & (\cos\omega\sin i) \end{bmatrix}$$

Space Link

Power flux density:

$$\Psi_{iso} = \frac{P_T}{4\pi r^2} \mathrm{W/m^2}$$

Carrier to noise ratio:

$$\frac{C}{N} = \frac{P_T G_T G_R}{k T_S B}\left(\frac{\lambda}{4\pi d}\right)^2$$

Gain of centre-fed paraboloidal antenna:

$$G = \frac{4\pi}{\lambda^2}\eta\, Area = \eta\left(\frac{\pi D}{\lambda}\right)^2$$

Rain Attenuation

Specific attenuation:

$$\alpha = aR_p^b \text{ dB/km}$$

Slant path length (for $\theta > 10°$):

$$L_S = \frac{h_R - h_0}{\sin\theta}$$

Horizontal projection:

$$L_G = L_S \cos\theta$$

Total attenuation due to rain:

$$A = \alpha L \text{ dB}$$

Effective path length:

$$L = L_S r_p$$

Values of a and b for circular polarization:

$$a_c = \frac{a_h + a_v}{2},\ b_c = \frac{a_h b_h + a_v b_v}{2a_c}$$

Table 1 Reduction Factors

p (%)	$r_p =$
0.001	$\frac{10}{10 + L_G}$
0.01	$\frac{90}{90 + 4L_G}$
0.1	$\frac{180}{180 + L_G}$
1	1

Table 2 Values for a and b for vertical and horizontal polarization

Frequency, GHz	a_h	a_v	b_h	b_v
1	0.0000387	0.0000352	0.912	0.88
2	0.000154	0.000138	0.963	0.923
4	0.00065	0.000591	1.121	1.075
6	0.00175	0.00155	1.308	1.265
7	0.00301	0.00265	1.332	1.312
8	0.00454	0.00395	1.327	1.31
10	0.0101	0.00887	1.276	1.264
12	0.0188	0.0168	1.217	1.2
15	0.0367	0.0335	1.154	1.128
20	0.0751	0.0691	1.099	1.065
25	0.124	0.113	1.061	1.03
30	0.187	0.167	1.021	1

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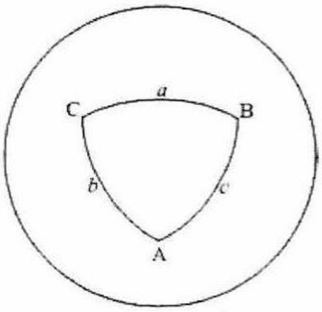
Reference Formulas From Plane and Spherical Trigonometry

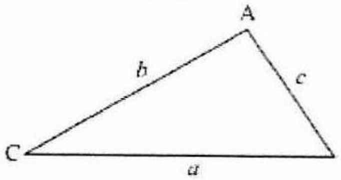


For any spherical triangle ABC whose side lengths a, b, and c, are measured by the great circle arcs subtended at the center of the sphere:

$$\frac{\sin A}{\sin a} = \frac{\sin B}{\sin b} = \frac{\sin C}{\sin c} \text{ (sine law)}$$

$\cos a = \cos b \cos c + \sin b \sin c \cos A$ *(cosine law for sides)*

$\cos A = -\cos B \cos C + \sin B \sin C \cos a$ *(cosine law for angles).*



For any plane triangle ABC

$c^2 = a^2 + b^2 - 2ab \cos C$ *(law of cosines)*

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c} \text{ (law of sines)}$$

and if

$$S = \frac{a+b+c}{2}, \text{ then } \tan\frac{C}{2} = \sqrt{\frac{(S-a)(S-b)}{S(S-C)}}$$

Table 3 Day Number for start of day

Date	Day number for start of day (midnight)
Jan 31	31
Feb 28 (29)	59 (60)
March 31	90 (91)
April 30	120 (121)
May 31	151 (152)
June 30	181 (182)
July 31	212 (213)
Aug 31	243 (244)
Sept 30	273 (274)
Oct 31	304 (305)
Nov 30	334 (335)
Dec 31	365 (366)