Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2017/2018

COURSE NAME	:	SATELLITE COMMUNICATION AND NAVIGATION
COURSE CODE	:	BEB 41303
PROGRAMME	:	BEJ
EXAMINATION DATE	:	JUNE/ JULY 2018
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS IN SECTION A. 2. ANSWER **TWO (2)** QUESTIONS IN SECTION B.

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

SECTION A – ANSWER ALL QUESTIONS IN THIS SECTION

Q1 (a) Describe **FOUR (4)** advantages of satellite communiation system as an alternative to the conventional communication network.

(4 marks)

(b) Describe the reasons why a satellite does not fall down to Earth and instead follow the orbit that has been set.

(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.

(6 marks)

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

(6 marks)

Q2 (a) The Two Line Element (TLE) data set for ASTRA 2E satellite which is located at 28.2° E is given as below:

```
ASTRA 2E
1 39285U 13056A   18099.37203603  .00000138  00000-0  00000-0 0  9995
2 39285   0.0718  43.1530 0002625 328.9027 347.9462  1.00269949 16481
```

(i) Extract the 5 Keplerian elements form the TLE set.

(6 marks)

(ii) Determine the exact altitude of the satellite from sea level (at zenith).

(2 marks)

(b) A SKY TV subscriber wants to watch TV programmes broadcasted by ASTRA 2E (28.2° E) from his home in Lancaster, United Kingdom (latitude 54.0466° N, longitude 2.8007° W). In order for that to happen, he needs to align his parabolic dish antenna to the exact satellite location in space. Given the satellite parameters as in **Q2(a)** and the Earth station – satellite geometry in **Figure Q2(b)**, analyze the parameters of the geometry that are,

(i) the slant range, d,

(4 marks)

(ii) azimuth angle, A_z,

(4 marks)

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

(2 marks)

(iv) tilt angle, T.

(2 marks)

Q3 (a) A ground station in Lancaster, United Kingdom is equipped with a 55 cm in diameter parabolic dish antenna with an efficiency of 55%. The station receives a Broadcasting Satellite Service (BSS) at KU-band frequency (12 GHz) from the ASTRA 2E satellite (longitude 28.2° E). The distance between the earth station and the satellite is 39,343.322 km. The effective isotropic radiated power (EIRP) is 58 dBW.

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

(3 marks)

(ii) Analyze the carrier-to-noise density ratio (C/N_0) at the dish interface. Assume $T_s = 400\ K$, antenna pointing loss of 0.36 dB, atmospheric loss is 0.2 dB and rain fade of 10 dB is predicted for 99.99% availability.

(5 marks)

(b) The ASTRA 2E satellite in **Q3(a)** receives an uplink broadcasting signal at 14 GHz from a ground station located in London, United Kingdom (51.5074 ° N, 0.1278° W). The ground station has an antenna with a gain of 60 dB and the distance between the ground station and satellite is 39,028.117 km. The antenna has an input power of 140 W and other transmission losses are estimated at 12 dB.

(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 of 58 dBW.

(5 marks)

(c) A satellite TWTA has to operate at its linear curve to reduce intermodulation noise. Power received by the satellite can either fall short or exceed the optimum working range of the satellite TWTA.

(i) Discuss the term 'saturation flux density' in satellite link design.

(2 marks)

(ii) Describe ways to ensure the TWTA will work in the linear region for both cases stated in **Q3(c)** as well as producing signal that achieve the stated satellite's effective isotropic radiated power (EIRP) contour.

(2 marks)

SECTION B – ANSWER ONLY TWO (2) QUESTIONS IN THIS SECTION

Q4 (a) State the **THREE (3)** conditions required for an orbit to be geostationary. Differentiate between geosynchronous and geostationary orbit.

(4 marks)

(b) A satellite in a particular orbit has an apogee height of 761.663 km and a perigee height of 757.08 km. Assuming a mean earth radius of 6371 km, determine;

(i) the semimajor axis,

(2 marks)

(ii) the eccentricity of the satellite's orbit, and

(2 marks)

(iii) the satellite angular velocity at perigee and apogee.

(4 marks)

(c) Satellites in orbit experience orbital perturbation effect that cause changes to the initial orbit parameters. Analyze the type and the effect of orbital perturbations on satellites in LEO and geostationary orbit.

(8 marks)

Q5 (a) Explain briefly the propagation impairments which mostly affect transmission at the frequency of 6 GHz.

(5 marks)

(b) An earth station located at altitude 500m from sea level is receiving satellite signals at an angle of elevation of 35°. The signal is circularly polarized at frequency of 4 GHz. The rain height is 2 km, and a rain rate of 8 mm/h is exceeded for 0.01 percent of the year. Analyze rain attenuation under these condition using **Table Q5(b)** and **Table Q5(c)**.

(7 marks)

(c) Describe the modes of interference that can occur in satellite communication systems.

(8 marks)

Q6 (a) In a Frequency Division Multiple Access (FDMA) network, a satellite transponder capability is said to be either bandwidth limited or power limited. Explain both limitations on the transponder operation.

(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 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) Code Division Multiple Access (CDMA) is a technique used to increase signals resistance to interference. One popular CDMA method is the direct-sequence spread spectrum (DS/SS).

(i) Describe the generation process of CDMA signal using DS/SS using suitable diagram.

(4 marks)

(ii) Sketch the power density of a signal after undergoing the spreading process.

(2 marks)

(d) 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 binary phase shift keying (BPSK) modulation. Calculate the processing gain in decibels.

(4 marks)

\- **END OF QUESTIONS** -

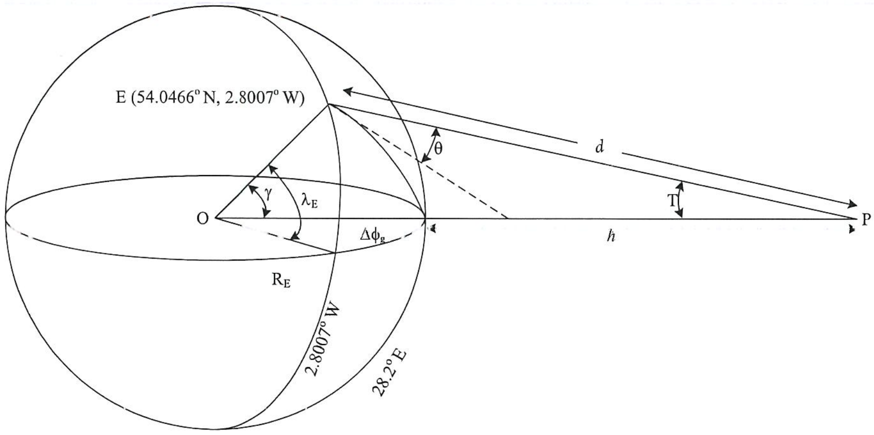

Figure Q2(b) Geostationary Orbit Geometry

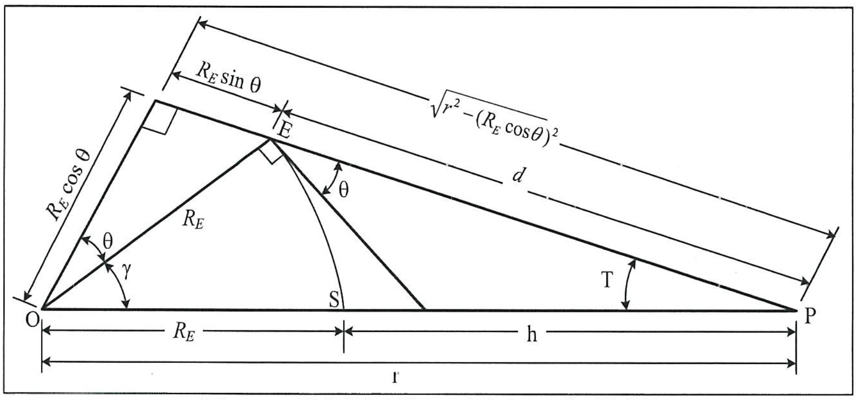

Figure Q2(b) Plane Triangle EOP

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2017/2018
COURSE : SATELLITE COMMUNICATION AND NAVIGATION
PROGRAMME : BEJ
COURSE CODE : BEB 41303

Table Elliptical Orbit Parameter Relationships

Given para-meters	Semimajor axis a	Semiminor axis b	Apogee radius r_a	Perigee radius r_p	Eccentricity e	Apogee velocity v_a	Perigee velocity v_p	Specific Angular Momentum h	Toal Specific Energy E	Period T
a, e	a	$a\sqrt{1-e^2}$	$a(1+e)$	$a(1-e)$	e	$\sqrt{\frac{\mu}{a}\left(\frac{1-e}{1+e}\right)}$	$\sqrt{\frac{\mu}{a}\left(\frac{1+e}{1-e}\right)}$	$\sqrt{\mu a(1-e^2)}$	$-\frac{\mu}{2a}$	$2\pi\sqrt{\frac{a^3}{\mu}}$
r_a, r_p	$\frac{1}{2}(r_a + r_p)$	$\sqrt{r_a r_p}$	r_a	r_p	$\frac{r_a - r_p}{r_a + r_p}$	$\sqrt{\left(\frac{2\mu}{r_a + r_p}\right)\frac{r_p}{r_a}}$	$\sqrt{\left(\frac{2\mu}{r_a + r_p}\right)\frac{r_a}{r_p}}$	$\sqrt{\frac{2\mu r_a r_p}{r_a + r_p}}$	$-\frac{\mu}{r_a + r_p}$	$\pi\sqrt{\frac{(r_a + r_p)^2}{2\mu}}$
a, r_a	a	$\sqrt{r_a(2a - r_a)}$	r_a	$2a - r_a$	$\frac{r_a - a}{a}$	$\sqrt{\frac{\mu}{a}\left(\frac{2a - r_a}{r_a}\right)}$	$\sqrt{\frac{\mu}{a}\left(\frac{r_a}{2a - r_a}\right)}$	$\sqrt{\frac{\mu}{a} r_a(2a - r_a)}$	$-\frac{\mu}{2a}$	$2\pi\sqrt{\frac{a^3}{\mu}}$
a, r_p	a	$\sqrt{r_p(2a - r_p)}$	$2a - r_p$	r_p	$\frac{a - r_p}{a}$	$\sqrt{\frac{\mu}{r_a}\left(\frac{r_p}{2a - r_p}\right)}$	$\sqrt{\frac{\mu}{r_a}\left(\frac{2a - r_p}{r_p}\right)}$	$\sqrt{\frac{\mu}{a} r_p(2a - r_p)}$	$-\frac{\mu}{2a}$	$2\pi\sqrt{\frac{a^3}{\mu}}$
e, r_a	$\frac{r_a}{1+e}$	$r_a\sqrt{\frac{1-e}{1+e}}$	r_a	$r_a\frac{1-e}{1+e}$	e	$\sqrt{\frac{\mu}{r_a}(1-e)}$	$\sqrt{\frac{\mu}{r_a}\frac{(1+e)^2}{1-e}}$	$\sqrt{\mu r_a(1-e)}$	$-\frac{\mu}{2r_a}(1+e)$	$2\pi\sqrt{\frac{r_a^3}{\mu(1+e)^3}}$
e, r_p	$\frac{r_p}{1-e}$	$r_p\sqrt{\frac{1+e}{1-e}}$	$r_p\frac{1+e}{1-e}$	r_p	e	$\sqrt{\frac{\mu}{r_p}\frac{(1+e)^2}{1-e}}$	$\sqrt{\frac{\mu}{r_p}(1-e)}$	$\sqrt{\mu r_p(1+e)}$	$-\frac{\mu}{2r_a}(1-e)$	$2\pi\sqrt{\frac{r_p^3}{\mu(1-e)^3}}$
v_a, v_p	$\frac{\mu}{v_a v_p}$	$\frac{2\mu}{(v_a + v_p)\sqrt{v_a v_p}}$	$\frac{2\mu}{v_a(v_a + v_p)}$	$\frac{2\mu}{v_p(v_a + v_p)}$	$\frac{v_a - v_p}{v_a + v_p}$	v_a	v_p	$\frac{2\mu}{v_a + v_p}$	$\frac{v_a v_p}{2}$	$\frac{2\pi\mu}{\sqrt{v_a^3 v_p^3}}$
v_a, r_a	$\frac{\mu r_a}{2\mu - r_a v_a^2}$	$r_a v_a\sqrt{\frac{r_a}{2\mu - r_a v_a^2}}$	r_a	$\frac{r_p^2 v_a^2}{2\mu - r_a v_a^2}$	$1 - \frac{r_a v_a^2}{\mu}$	v_a	$\frac{2\mu - r_a v_a^2}{r_a v_a}$	$r_a v_a$	$\frac{2}{r_a} - \frac{v_a^2}{\mu}$	$2\pi\mu\left(\frac{r_a}{2\mu - r_a v_a^2}\right)^{\frac{3}{2}}$
v_p, r_p	$\frac{\mu r_a}{2\mu - r_p v_p^2}$	$r_p v_p\sqrt{\frac{r_p}{2\mu - r_p v_p^2}}$	$\frac{r_p^2 v_p^2}{2\mu - r_p v_p^2}$	r_p	$\frac{r_p v_p^2}{\mu} - 1$	$\frac{2\mu - r_p v_p^2}{r_p v_p}$	v_p	$r_p v_p$	$\frac{2}{r_p} - \frac{v_p^2}{\mu}$	$2\pi\mu\left(\frac{r_p}{2\mu - r_p v_p^2}\right)^{\frac{3}{2}}$

Table Q5(b) 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 Q5(c) 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

Rain Attenuation Formulae

Specific attenuation: $\alpha = aR_p^b$ dB/km	Total attenuation due to rain: $A = \alpha L$ dB	Slant path length (for $\theta > 10°$): $L_S = \frac{h_R - h_0}{\sin\theta}$
Horizontal projection: $L_G = L_S \cos\theta$ Effective path length: $L = L_S r_p$	Values of a and b for circular polarization: $a_c = \frac{a_h + a_v}{2}$, $b_c = \frac{a_h b_h + a_v b_v}{2a_c}$	

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2017/2018
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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^3s^{-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:

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

Carrier to noise ratio:

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

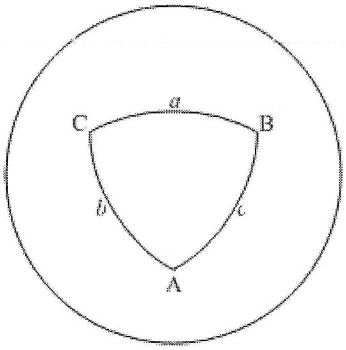
Gain of centre-fed paraboloidal antenna:

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

FINAL EXAMINATION

SEMESTER / SESSION : SEM II / 2017/2018 PROGRAMME : BEJ
COURSE : SATELLITE COMMUNICATION AND NAVIGATION COURSE CODE : BEB 41303

Reference Formulas From Plane and Spherical Trigonometry

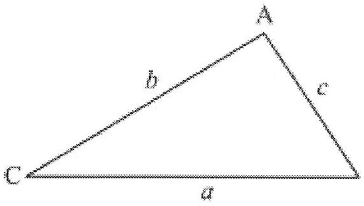


For any spherical triangle ABC whose side lengths *a, b,* and *c*, are measured by the great circle arcs subtended at the center of the sphere:

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

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

and if

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

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