UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2015/2016

COURSE NAME : SATELLITE COMMUNICATION AND NAVIGATION

COURSE CODE : BEB 41303

PROGRAMME : BACHELOR OF ELECTRONIC ENGINEERING WITH HONOURS

EXAMINATION DATE : DECEMBER 2015/ JANUARY 2016

DURATION : 3 HOURS

INSTRUCTION :

1. ANSWER **ALL** QUESTIONS IN SECTION A.
2. ANSWER **TWO (2)** QUESTIONS IN SECTION B.

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

SECTION A – ANSWER ALL QUESTIONS IN THIS SECTION

Q1 (a) Describe briefly the advantages offered by satellite communication.

(4 marks)

(b) Differentiate between a geosynchronous orbit and geostationary orbit.

(4 marks)

(c) Global navigation satellite such as the NAVSTAR GPS uses the Medium Earth Orbit (MEO) as the choice of orbit for their navigation service. Justify the choice of this orbit for this type of service.

(6 marks)

(d) People living in high latitude country often has limited satellite service from geostationary orbit. Describe the reason for this problem and discuss the solution employed to overcome the problem.

(6 marks)

Q2 (a) The Two Line Element Set for the satellite MEASAT-3b located at 91.5° E is given as below:

```
MEASAT-3B
1 40147U 14054B   15303.63856976 -.00000261  00000-0  00000+0 0  9991
2 40147   0.0450  45.9799 0001569 208.0747 105.9528  1.00268547  4231
```

(i) Determine the epoch date and time.

(3 marks)

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

(6 marks)

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

(1 marks)

(b) An Astro subscriber wants to watch TV programmes broadcasted by MEASAT-3b from his home in Sandakan, Sabah, Malaysia (latitude 5.8333° N, longitude 118.1167° E). 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)**, determine,

(i) the slant range d,

(4 marks)

(ii) azimuth angle, A_z,

(3 marks)

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

(2 marks)

(iv) tilt angle, T.

(1 marks)

Q3 (a) A 3 m dish in Sandakan, Sabah (latitude 5.8333° N, longitude 118.1167° E) is used to receive KU-band signals from a MEASAT-3b satellite (longitude 91.5° E) where the distance between the transmitter and receiver is estimated to be 36609 km. The contour of the satellite footprint is given in **Figure Q3 (a).** Assume a rain fade of 10 dB is predicted for 99.99% availability. Also assume the efficiency of the antenna is 0.55 and atmospheric loss is 0.2 dB.

(i) Analyze the carrier-to-noise density ratio (C/N_0) at the dish interface. Assumed T_s = 400 K and antenna pointing loss of 0.36 dB.

(10 marks)

(ii) If the power fed to the earth station and satellite antennas are 100 W and 130 W respectively, calculate the amount of power received at the satellite.

(5 marks)

(iii) If the uplink requires an input *back-off* of 11 dB at the travelling tube wave amplifier (TWTA), and if C/N_0 at the satellite receiver is 74.5 dBHz, and the satellite G/T = 16 dBK^{-1}, evaluate the required saturation flux density for the uplink. Assume the receiver feeder losses amount to 0.6 dB.

(5 marks)

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

Q4 (a) A geostationary satellite is to be launched into the geostationary orbit by means of Hohmann transfer orbit. The launch site is located at French Guiana (latitude 5.3° N) and the initial satellite injection will place the satellite at altitude of 250 km.

(i) Explain the benefit of having a launched site near the equator.

(2 marks)

(ii) Discuss the advantages of using a transfer orbit.

(2 marks)

(b) The initial injection process in **Q4 (a)** manages to insert the satellite into a co-planar parking orbit (inclination = 6°). Assuming the Earth equatorial radius $R_e = 6378$ km, and the final geostationary orbit of altitude $h = 35786$ km, determine;

(i) the circular velocity at the parking and geostationary orbits.

(3 marks)

(ii) Analyse velocity increment (Δv) needed at both perigee and apogee in order to do inclination correction and put the satellite in the geostationary orbit.

(13 marks)

Q5 (a) Describe atmospheric scintillation and its effect on satellite signals.

(5 marks)

(b) An earth station located at mean sea level is transmitting signals to a satellite at angle of elevation of 35°. The signal is vertically polarized at frequency of 12 GHz. The rain height is 1 km, and a rain rate of 10 mm/h is exceeded for 0.001 percent of the year. Analyze rain attenuation under these condition.

(6 marks)

(c) Depolarization happens when signals travel through depolarizing medium either in the ionosphere or upper atmosphere. Two measures are used to quantify the effects of depolarization; cross-polarization discrimination (XPD) and polarization isolation (I). Formulate both measures with the aid of suitable diagrams.

(9 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 $[C/N]$ value 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 -

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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, $\mu = 3.986 \times 10^{14}$ $\mathrm{m^3 s^{-2}}$
Earth rotation rate around the Sun = $0.9856°$ /day
Boltzmann's constant, $k = 1.3806 \times 10^{-23}$ $\mathrm{m^2\,kg\,s^{-2}\,K^{-1}}$
Speed of light, $c = 3 \times 10^{8}$ $\mathrm{ms^{-1}}$

FORMULAE

The nodal precession (regression) rate:

$$\dot{\Omega} = -\frac{9.964}{(1-e^2)^2}\left(\frac{R_E}{a}\right)^{3.5} \cos i \text{ deg/day}$$

The apsidal rotation rate:

$$\dot{\omega} = \frac{4.982}{(1-e^2)^2}\left(\frac{R_E}{a}\right)^{3.5} (5\cos^2 i - 1) \text{ deg/day}$$

Specific attenuation:

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

Total attenuation due to rain:

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

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

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

Effective path length:

$$L = L_S r_p$$

Horizontal projection:

$$L_G = L_S \cos\theta$$

Carrier to noise ratio

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

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

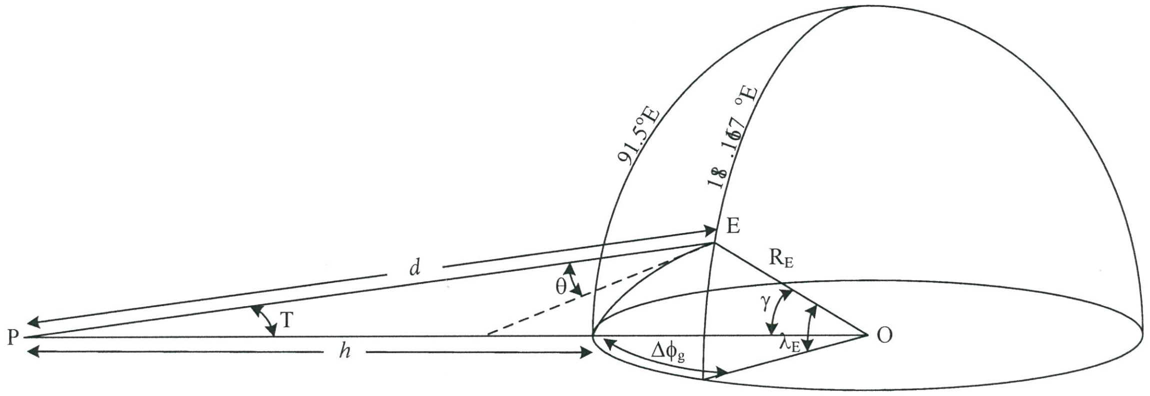
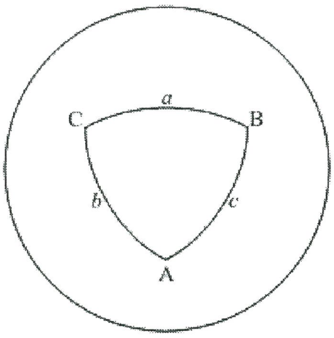


Figure Q2(b)



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:

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

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

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

For any plane triangle ABC

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

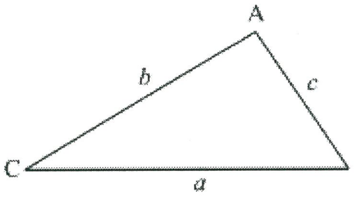
$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c} \text{ (law of sines)}$$

and if

$$S = \frac{a+b+c}{2}$$

then

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



MEASAT-3b Ku-Band

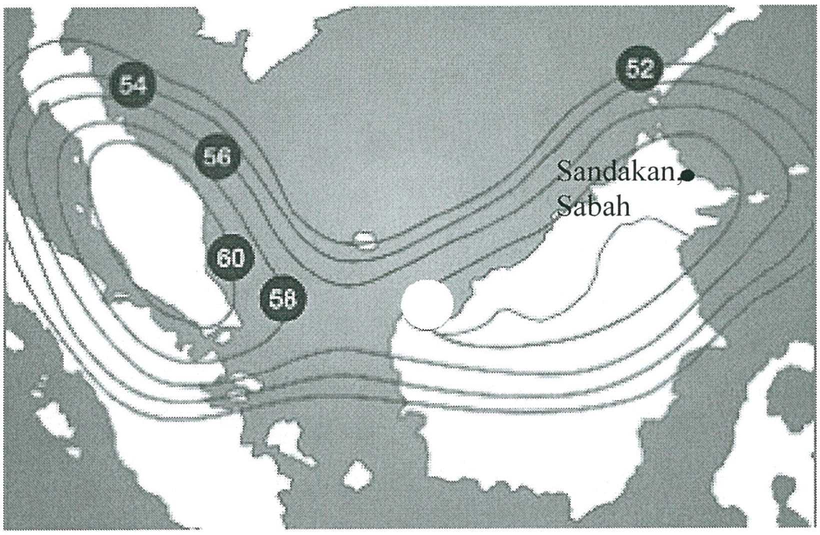


Figure Q3 (a)

Table Q2 Elliptical Orbit Parameter Relationships

Given parameters	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	Total 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	$r_p v_p$	$\frac{2}{r_p} - \frac{v_p^2}{\mu}$	$2\pi\mu\left(\frac{r_p}{2\mu - r_p v_p^2}\right)^{\frac{3}{2}}$