UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2015/2016

COURSE NAME	:	SATELLITE COMMUNICATION AND NAVIGATION
COURSE CODE	:	BEB 41303
PROGRAMME	:	BEJ
EXAMINATION DATE	:	JUNE/ JULY 2016
DURATION	:	3 HOURS
INSTRUCTIONS	:	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) Describe satellite station keeping activity and its importance in satellite system.
(4 marks)

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

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

(i) Justify the choice of this orbit for this type of service.
(4 marks)

(ii) Briefly describe the process of getting a position fix using GPS satellite.
(4 marks)

Q2 (a) The Two Line Element (TLE) 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 mark)

(b) A subscriber wants to watch TV programmes broadcast 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 mark)

Q3 (a) An earth station with 10 m parabolic dish antenna with efficiency of 55% located in Langkawi Island, Kedah is used to communicate at KU-band frequency with the MEASAT-3B satellite (longitude 91.5° E). The distance between the earth station and satellite is calculated to be 35909 km. The effective isotropic radiative power (EIRP) contour of the satellite footprint is given in **Figure Q3(a).**

(i) 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.

(10 marks)

(ii) If the power fed to the earth station and satellite antennas are 100 W and 120 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 $G/T = 14$ 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 using sea launch platform located at the Earth's equatorial line. Satellite will initially be injected into parking orbit at altitude of 185 km.

(i) Discuss this method of sending geostationary satellite into orbit.

(4 marks)

(b) The initial injection process in **Q4(a)** manages to insert the satellite into a co-planar parking orbit (inclination = 0°). 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.

(4 marks)

(ii) Analyze velocity increment (Δv) needed at both perigee and apogee.

(6 marks)

(c) A satellite moves in space at velocity exceeding 3 km/s. This high velocity give rise to a phenomena known as Doppler effect.

(i) Describe Doppler effect and its consequence to satellite communication using suitable diagram.

(3 marks)

(ii) In the search for Malaysia Airlines Flight 370 (MH370), a new technique was developed to locate the last position of the airplane using Doppler effect. Describe the idea behind this technique.

(3 marks)

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

(4 marks)

(b) An earth station located at mean sea level is receiving satellite signals at an angle of elevation of 70°. The signal is circularly polarized at frequency of 12 GHz. The rain height is 2 km, and a rain rate of 50 mm/h is exceeded for 0.001 percent of the year. Analyze rain attenuation under these condition.

(6 marks)

(c) List the **FOUR (4)** modes of inteference between 2 satellite systems and suggest possible actions that can be taken to reduce the inteferences.

(10 marks)

Q6 (a) Modern satellite service employs Time Division Multiple Access due to the fact that majority of the data being transmitted are in digital form.

(i) Briefly explain the TDMA operation.

(2 marks)

(ii) State the technique used to ensure each station is synchronised to the same timing system.

(2 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.

(i) 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, $\mu = 3.986 \times 10^{14}$ 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

Carrier to noise ratio:

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

Power flux density:

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

Gain of centre-fed paraboloidal antenna:

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

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:

$$L_G = L_S \cos\theta$$

Values of a and b for circular polarization:

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

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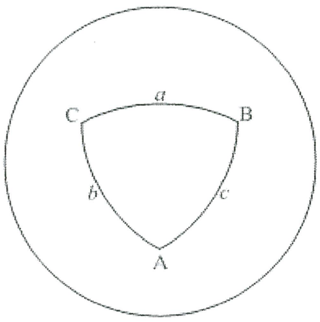
Reference Formulas From Plane and Spherical Trigonometry

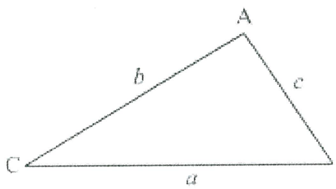


For any spherical triangle ABC whose side lengths *a, b,* and *c*, are measured by the great circle arcs subtended at the center of the sphere:

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

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

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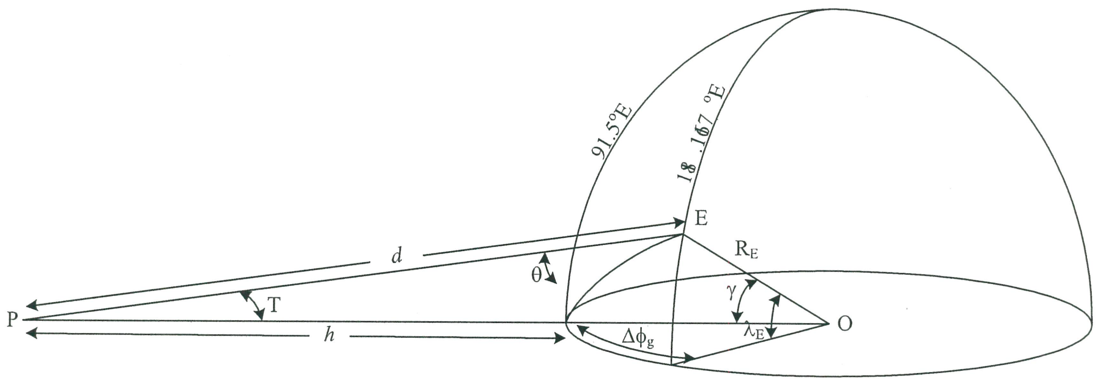

Figure Q2(b) Earth Station – Geostationary Satellite Geometry

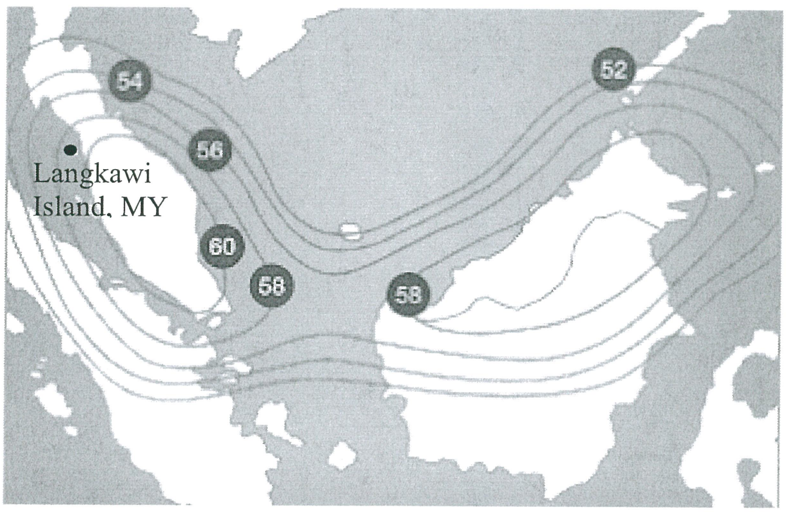

Figure Q3 (a) MEASAT-3B Ku-Band Contour

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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	$\frac{2\mu-r_a v_a^2}{r_a v_a}$	$r_a v_a$	$\frac{2}{r_a}-\frac{v_a^2}{\mu}$	$2\pi\mu\left(\frac{r_a}{2\mu-r_a v_a^2}\right)$
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	$r_p v_p$	$\frac{2}{r_p}-\frac{v_p^2}{\mu}$	$2\pi\mu\left(\frac{r_p}{2\mu-r_p v_p^2}\right)$