

## Department of Electrical Engineering

### Assignment

Date: 13/04/2020

### Course Details

Course Title: Radar and Satellite Communications

Module: 8th

Instructor: Dr Shahryar Shafique Qureshi

Total Marks: 30

### Student Details

Name: SAQIB ALI

Student ID: 13041

Student

Signature:



Q1		Answer the following questions	Marks 15
			CLO 01
	(a)	Explain why some satellites employ cylindrical solar arrays, whereas others employ solar-sail arrays for the production of primary power. State the typical power output to be expected from each type. Why is it necessary for satellites to carry batteries in addition to solar-cell arrays?	Marks 05
	(b)	Explain why an omnidirectional antenna must be used aboard a satellite for telemetry and command during the launch phase. How is the satellite powered during this phase?	Marks 05
	(c)	Explain what is meant by frequency reuse, and describe briefly two methods by which this can be achieved in a satellite communication system.	Marks 05
Q2		A LEO satellite is in a circular orbit 550 km above the earth. Assume the average radius of the earth is 6378 km. Assume the earth eccentricity is 0.	Marks 05
		a) Determine the orbital velocity of the satellite in m/sec b) What is the orbital period, in minutes, for the LEO satellite? c) From the above, determine the orbital angular velocity for the satellite, in radians/sec.	CLO 02
Q3		The orbit for an earth-orbiting satellite orbit has an eccentricity of 0.15 and a semimajor axis of 9000 km. Determine	Marks 05
		a) its periodic time b) the apogee height c) the perigee height. Assume a mean value of 6371 km for the earth's radius.	CLO 02
Q4		A communications satellite is located in geostationary orbit at 90°W longitude. Calculate the range, azimuth, and elevation angle to the satellite as seen from ground stations located in altitude 35°N and longitude 100°W.	Marks 05
			CLO 02

Question No 1 (a):- Explain why some satellites employ cylindrical solar arrays. whereas others employ solar-sail arrays for the production of the power. state the typical power output to be expected from each type. why is it necessary for satellite to carry batteries in addition to solar-cell arrays.?

Some satellite employ cylinder solar array and some solar sail array both are using different techniques to control the attitude of satellite. spin stabilized or in spin stabilized, spinning the satellite provides the gyroscopic stiffness to the satellite. Simple method to spin the entire satellite. In such a satellite to retain continuous earth pointing the antenna must be possess a toroidal beam shap or employ



electronic steering. Dual spin satellites have antenna and solar panel on a separate which is spun in main spinning body in system maintains continuous visibility of the earth and solar panel continuously pointing the sun. The satellite may be spun either around the axis of maximal moment of inertia or minimal moment of inertia.

The solar panel can be either despun as said above may be mounted the body the cylindrical satellite ~~has~~ has advantage that despining the solar-panel is not required. But this require no of solar-cell to be more than half of the cells are always away from sun. The size of solar-panel is to be more than ~~two~~ twice that of the despun type panel. One more advantage of this body mounted solar panels is that ~~more~~ since more half of the solar cells away from sun

and are continuously rotating. The heat dissipation of solar cells is taken care of automatically. The cells which get heated when exposed to sun dissipate the heat when they are turned away from the sun. So the burden on thermal subsystem can be reduced to some extent.

Station keeping in ~~the spin axis~~ north-south direction is maintained by firing the thrusters parallel to the spin axis in continuous mode. The east-west station keeping is obtained by firing thrusters mounted perpendicular to the spin axis.

In three axis stabilization satellite body is maintained fixed in space. Difficult to achieve three-axis stabilized solely by the thrusters because of the lack of adequate stiffness is achieved by using momentum wheels rotate within body of the spacecraft. Accelerating or de-accelerating the momentum wheel provides control.



Many Satellite undergoes around eclipses in a year with maximum eclipse duration of about 70 minutes. Therefore it is necessary for a satellite to carry additional batteries provide electrical supply to the spacecraft, which occur randomly in the year. If by chance there is eclipse occurs the battery should have more capacity to satellite.

(b) Explain why omnidirectional antenna must be used aboard a satellite for telemetry and command during launch phase. How is the satellite powered during this phase?

Solution:- During orbit raising when or when the attitude control is lost an antenna with near omnidirectional pattern is used. During operational phase the communication antenna is used. Distributed telemetry systems are increasingly being favored. In this digital encoders

are located in each subsystem of the satellite and data from each encoder are sent to a central wire connections to a large extent. Also allows easy expansion of the initial design and facilities testing during assembly of the satellite. The command subsystem controls the satellite. The satellite operating through all phases of the by receiving and decoding commands from ground station. It also generates a verification signal and upon receipt of an execute signal carries out commands. The command subsystem also serves as an uplink receiver for ringing signals. Some of the signals are: transponder, switching, switch matrix reconfiguration, antenna control, controlling direction speed of solar array drive, battery reconditioning thruster firing switch heaters of various subsystems etc. Three hundred different command signals are possible on board. The reliability and interpretation



of these signals is vital. If the data is misinterpreted all the control will go wrong. For example if implemented in time, the satellite may drift out of its home. A fail safe operation has to be achieved under low conditions.

A commonly used safety feature demands verification of each command by the satellite control center to reduce the impact of high bit error rate, coding and repetition of data are employed.

Figure 1 shows the typical block diagram of command system. The antenna used during orbit raising phase are ~~near~~ omnidirectional to maintain contact for all possible ~~axis~~ orientation of satellite during critical maneuvers. Converts the RF to baseband and ~~its~~ this is decode the decoder. The command is stored in the memory before execution for verification. The system is duplicated for improving reliability.

## Block Diagram:-

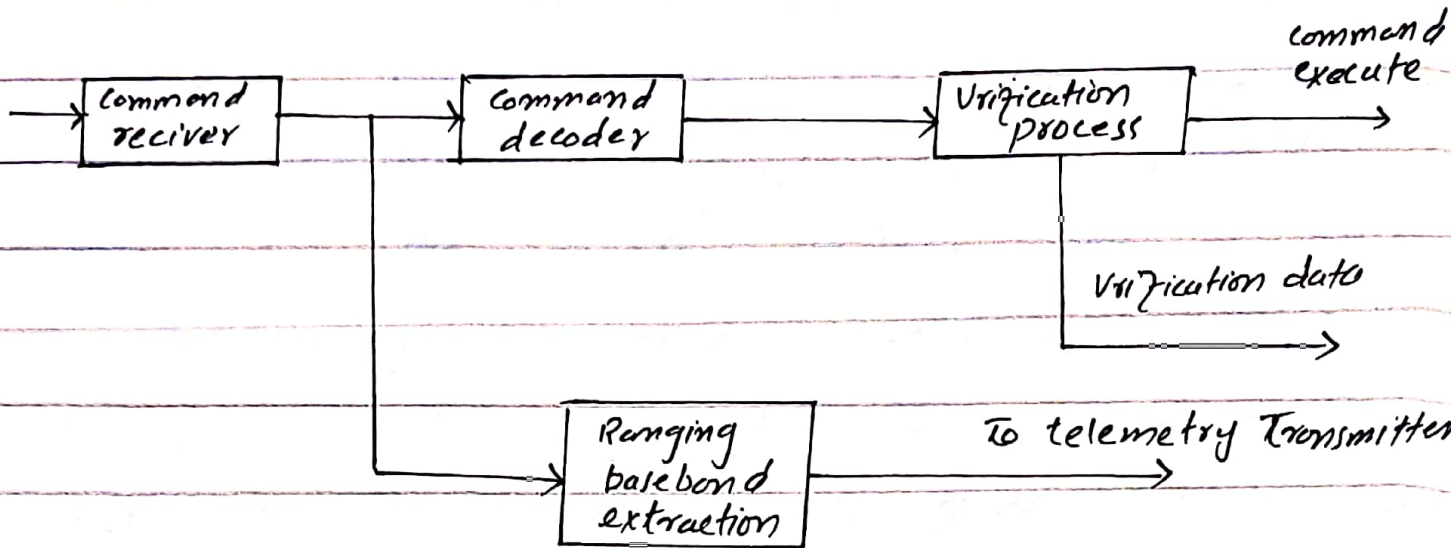


Figure 1

(C) Explain what is meant by frequency reuse and describe briefly two methods by which this can be achieved in a satellite communication system.

Frequency reuse antenna:-

There are two

main type of frequency.

(i) Spatial beam separation.

(ii) Orthogonal polarization.



ii) Spatial beam separation :- In spatial beam separation frequency reuse the same frequency band are used for transmission and reception to geographically separated regions of the earth surface. For example the positioning of each satellite in the Intelsat global system has been selected to provide an east and west zone by locating each spacecraft over ocean. The angular separation of the east and west zones is about  $10^\circ$  and the coverage zones approximately  $5^\circ$  wide. By generating a very carefully shaped beams using large cluster feeds it is possible to reduce the sidelobes from level in the other zone. For FM transmission it is necessary to keep interference b/w beams down to about 25-dB. With digital transmission system, higher interference levels can be tolerated upto 17-dB. The antennas are to be designed to configure in orbit so that the beams be tailored to a

specific mission. For example an antenna can have a reflector and 13 horn arranged in groups and fed by 15 variable power dividers. The transmitter power is split b/w the feed horns according to the variable power divider settings which can be controlled from earth by telecommand. This allows a single design of to be fitted to spacecraft that will be operate it different longitudes and serves different geographical areas.

### (ii) Orthogonal polarization :-

In orthogonal polarization frequency reuse each beam is generated in polarizations. For example left hand circular polarization and right hand circular polarization overlay the hemi beams. This places a very stringent requirement on the antenna which must maintain isolation b/w the two polarizations of at least 25dB throughout the coverage zones of both beams.



Reflector antennas tend to generate cross-polarized from the feed system curvature of the reflector. Careful matching of the feed radiation characteristic to the curvature of the reflector, which is usually offset avoid blockage by large feed cluster can achieve cross-polar isolation b/w beams of required 25 dB. The development of these multiple-beam dual polarization antenna was the result of a great deal of work by microwave antenna specialists. In many larger ~~satellite~~ satellites the antennas use offset paraboloidal reflectors of feeds provide carefully controlled beam shapes. The feed are on the body of spacecraft and reflection folds down to provide compact structure in orbit, arms are swung out and locked in place to hold the reflector in the correct position. When the spacecraft is in geostationary orbit it is required to move the ~~a~~ large reflector. Invariably all systems being planned or in operation deploy multiple spot beam antennas to

maximize spacecraft power usage and spectrum reuse. Technology over 300 spot beams in the L band using large reflectors of 8-20m diameter and multiple combination is available. The ~~speak~~ peak of spot is of order of 30-40 dB with an out of band 20dB within spot terrestrial cellular like reuse grid. A number of techniques have been proposed to generate spot beams with such stringent requirements.



Question No 2 :- A LEO satellite is in a circular orbit 550 km above the earth.

Assume the average radius of the earth is 6378 km. Assume the earth eccentricity is 0.

(a) Determine the orbital velocity of the satellite in m/sec.

(b) What is the orbital period in minutes for the LEO satellite?

(c) From the above determine the orbital angular velocity for the satellite in radian/sec.

Solution :-

Height of orbit from the earth = 550 km

Radius of the earth = 6378 km.

Calculate the total orbital radius

$$r = r_e + h_{orb}$$

$$r = 550 \text{ km} + 6378 \text{ km}$$

$$r = 6928 \text{ km}$$

(a) Orbital velocity.

We know

$$V = (\mu/r)^{1/2}$$

$\mu$  = the Kepler constant =  $3.986004 \times 10^5 \text{ Km}^2/\text{s}^2$

putting the value.

$$V = \sqrt{\frac{3.986004 \times 10^5 \text{ Km}^2/\text{s}^2}{6928}}$$

$$V = \sqrt{\frac{3.986004 \times 100000 \text{ Km}^2/\text{s}^2}{6928}}$$

$$V = \sqrt{\frac{398600.4 \text{ Km}^2/\text{s}^2}{6928}}$$

$$V = \sqrt{57.534 \text{ Km}^2/\text{s}^2}$$

$$V = \sqrt{7.585 \text{ Km/s}}$$

The velocity in m/sec



$$v = 7.585 \times 1000 \text{ m/sec}$$

$$v = 7585 \text{ m/sec}$$

(b) The orbital period from the Kepler 3rd law is given by

$$T^2 = \left[ \frac{4\pi}{\mu} \right] a^3$$

Taking square root both side

$$\sqrt{T^2} = \sqrt{\left[ \frac{4\pi}{\mu} \right] a^3}$$

Putting the value

$$r = 6928 \text{ km}$$

$$\mu = 3.986004 \times 10^5 \text{ km}^2/\text{s}^2$$

Since  $\pi = 3.14$

putting the value

$$T = \sqrt{\left[ \frac{4 \times (3.14)^2}{3.986004 \times 10^5 \text{ km}^2/\text{s}^2} \right] (6928)^3}$$

We know that ~~orbit~~ circular orbit

$$a = r.$$

$$T = 4(3.14)^2$$

$$T = \sqrt{\frac{4(9.8596)}{3.986004 \times 10^5}} (6928)^2$$

$$T = \sqrt{\left[ \frac{39.4384}{3.986004 \times 100000} \right]} (332524490752)$$

$$T = \sqrt{\frac{13114233876073.678}{3.986004 \times 100000}}$$

$$T = \sqrt{\frac{131142338760.73.678}{398600.4}}$$

$$T = \sqrt{32900704.254}$$

$$T = 5735.913 \text{ sec}$$



(16)

Now  $T$ 

$$T = \frac{5735.913 \text{ sec}}{60}$$

$$T = 95.59 \text{ minutes}$$

(c) For calculating orbital angular velocity.  
for the satellite we have time

$$T = 5735.915 \text{ sec}$$

We know that one revolution of earth  
is  $2\pi$  which takes the time to  
complete.

$\omega$  = angular velocity

We know

$$\omega = 2\pi/T$$

$$\omega = \frac{2(3.14)}{5735.913}$$

$$\omega = \frac{6.28}{5735.913}$$

$$\omega = 0.0010948 \text{ rad/sec}$$

Question No 3 :- The orbit of an earth orbiting satellite has an eccentricity of 0.15 and a semi-major axis of 9000 km. Determine

- (a) Its periodic time.
- (b) The apogee height.
- (c) The perigee height.

Solution :-

Data

$$a = r = 9000 \text{ km}$$

$$e = 0.15$$

$$R = 6371 \text{ km}$$

We know that

$$P = \frac{2\pi}{n}$$

$$n = \sqrt{\frac{\mu}{a^3}}$$

$$n = \sqrt{\frac{6371}{(9000)^2}}$$



$$n = 7.394 \times 10^{-4} \text{ rad/sec}$$

Now

$$P^{2(3.14)} \\ 7.394 \times 10^{-4}$$

$$P = 8,497 \text{ sec}$$

(b)

$$r_a = a(1+e)$$

$$r_a = 9000(1+0.15)$$

$$r_a = 9000(1.15)$$

$$r_a = 10350 \text{ Km}$$

$$h_a = r_a - R$$

$$h_a = 10350 - 6371$$

$$h_a = 3979 \text{ Km}$$

(c)

$$r_p = a(1-e)$$

$$r_p = 9000(1-0.15)$$

$$r_p = 9000(0.85)$$

$$r_p = 7650 \text{ Km}$$

$$h_p = 7650 - 6371 \Rightarrow$$

$$1279 \text{ Km}$$

Question No 48- A communication satellite is located in geostationary orbit at  $90^\circ W$  longitude. Calculate the range azimuth and elevation angle to the satellite as seen from ground stations located at altitude  $35^\circ N$  and longitude  $100^\circ W$ .

Solution:-

Data

For satellite

$$\text{Longitude} = 90^\circ W$$

$$\text{Latitude} = 0^\circ$$

Find

range,  $d$

azimuth angle  $\theta_z$

elevation angle  $\theta$

having

$$\text{Latitude} = 35^\circ W$$

$$\text{Longitude} = 100^\circ W$$

$$LE = 35^\circ N = +35^\circ$$

$$IE = 100^\circ W = -100$$



$$L_s = 0^\circ$$

$$I_s = 90^\circ W = -90$$

Find differential longitude

$$B = I_E - I_s$$

$$= (-100) - (-90)$$

$$= -100 + 90$$

$$B = -10$$

Now we determine the earth radius at the Earth station which as R

So

$$R = \sqrt{l^2 + z^2}$$

$$l = \left[ \frac{r_e}{1 - e^2 \sin^2(LE)} + H \right] \cos(LE)$$

$$r_e = \text{Equatorial Radius} = 6378.13 \text{ km}$$

$$It = \text{Attitude of earth station} = 0$$

Putting the value.

(21)

$$= \left[ \frac{6378.13}{\sqrt{1 - (0.08142)^2 \sin^2 35}} + 0 \right] \cos 35$$

$$= \left[ \frac{6378.13}{\sqrt{(1 - 0.0066945125)(0.3289)}} \right] (0.819)$$

$$= \left[ \frac{6378.13}{\sqrt{(0.993305)(0.3289)}} \right] (0.819)$$

$$= \left[ \frac{6378.13}{\sqrt{0.3266981}} \right] (0.819)$$

$$= \left[ \frac{6378.13}{0.571575} \right] (0.819)$$

$$= (11158.86804) (0.819)$$

$$\boxed{L = 9139.112924 \text{ km}}$$



Now find  $z$

$$z = \left( \frac{(r_e - r_e^2)}{\sqrt{1 - r_e^2 \sin^2(LE)}} + H \right) \sin(LE)$$

$$z = \left[ \frac{6378.13 (1 - (0.08182)^2)}{\sqrt{(1 - 0.0066945124) (0.3289)}} \right] (0.573)$$

$$z = \left[ \frac{6378.13 (1 - (0.08182)^2)}{\sqrt{(0.993305) (0.3289)}} \right] (0.573)$$

$$z = \left[ \frac{6378.13 (0.993305)}{\sqrt{(0.993305) (0.3289)}} \right] (0.573)$$

$$z = \left[ \frac{6335.4284}{\sqrt{0.3266941}} \right] (0.573)$$

$$z = \left[ \frac{6335.4284}{0.571575} \right] (0.573)$$

$$z = (11084.1593) (0.573)$$

$$z = 6351.2232 \text{ km.}$$

Now

$$R = \sqrt{l^2 + z^2}$$

$$R = \sqrt{(9139.1129)^2 + (6351.2232)^2}$$

$$R = \sqrt{83523384.5989 + 40338036.1362}$$

$$R = \sqrt{123861420.7351}$$

$$R = 11129.3045 \text{ km}$$

$$\psi_E = \tan^{-1}(z/l)$$

$$= \tan^{-1} \frac{6351.2232}{9139.1129}$$

$$\psi_E = \tan^{-1} 0.694$$

$$\psi_E = 34.76$$



Find rang, d

$$d = \sqrt{R^2 + r_s^2 - 2Rs \cos(\psi_E) \cos B}$$

$$d = \sqrt{(11129.3042)^2 + (42164.17)^2 - 2(11129.3042)(42164.17) \dots \dots \cos 34.76 \cos(-10)}$$

$$d = \sqrt{123861412 + 1777817232 - 2(\overset{469257874.3}{\cancel{379096543.4}})(0.821)(0.964)}$$

$$d = \sqrt{123861412 + 1777817232 - 2(379096543.4)}$$

$$d = \sqrt{123861412 + 1777817232 - 758193086.7}$$

$$d = \sqrt{1901678644 - 758193086.7}$$

$$d = \sqrt{1143485557}$$

$$d = 33815.46329 \text{ km.}$$

Now find the elevation angle  $\theta$

$$\theta = \cos^{-1} \left( \frac{r_e + h_{gsb}}{d} \sqrt{1 - \cos^2(B) \cos^2(l_e)} \right)$$

$$= \cos^{-1} \left( \frac{6378.14 + 35786}{33815.46} \sqrt{1 - \cos^2(-10) \cos^2(35)} \right)$$

$$= \cos^{-1} \left( \frac{42164.14}{33815.46} \sqrt{1 - (0.969)(0.671)} \right)$$

$$= \cos^{-1} \left( (1.2468) \sqrt{1 - 0.650199} \right)$$

$$= \cos^{-1} \left( (1.2468) \sqrt{0.349801} \right)$$

$$= \cos^{-1} (1.2468)(0.5914)$$

$$= \cos^{-1} 0.7378 (0.737)$$

$$\boxed{\theta = 42.52^\circ}$$



Find the azimuth angle we have need some parameter to find the azimuth angle. First of all we determine the intermediate angle  $A$ .

$$B = \cos^{-1} (\cos(B) \cos(LE))$$

$$B = \cos^{-1} (\cos(10) \cos(35))$$

$$B = \cos^{-1} (0.984)(0.819)$$

$$B = \cos^{-1} (0.8058)$$

$$B = 36.30^\circ$$

Now

$$A_i = \sin^{-1} \frac{\sin(B)}{\sin(\beta)}$$

$$A_i = \frac{\sin(-10)}{\sin(36.30)}$$

$$A_i = \sin^{-1} (0.173/0.592) \rightarrow \underline{A_m}$$