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**B.Electrical Engineering**

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**Subject:**

**radar and satellite communication**

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Q1. which type of Satellite orbit provides the best performance for a communications network for each of the following.

- (a) ~~max~~ minimum free space path loss.
- (b) Best coverage of high latitude location.
- (c) Full global coverage for a mobile communication network.
- (d) minimum latency (time delay) for voice and data networks.
- (e) Ground terminals with little or no antenna tracking required.

Ans:

- (a) The LEO orbits have minimum free space path losses, because these orbits are nearer to the earth and thus losses are minimum.
- (b) LEO orbit satellite also provides a good coverage to high latitude area.



(c) Satellite in GSO orbits give full global coverage for a mobile communication network.

Because GSO Satellite sees about one-third of the earth's surface and they are  $120^\circ$  apart each other as to cover the whole earth we need only three GSO satellites.

(d) LEO Satellite provides minimum latency as they are nearer.

(e) At GSO orbit the satellites complete its revolution equal to the earth rotation i.e. 23 hrs and 56 min for one satellite revolution is required, which act as a stationary, so for them ground terminal with latitude no antenna tracking required.



Q2: An Ess ground terminal located in Chicago, IL, at latitude  $41.5^{\circ}\text{N}$  and longitude  $87.6^{\circ}\text{W}$  has access to two Cirs Satellite, one stationed at  $70^{\circ}\text{W}$  longitude and the second at  $135^{\circ}\text{W}$  longitude. which satellite will provide the more reliable link (higher elevation angle) for the ground terminal? The ground terminal elevation above sea level is  $0.5\text{km}$ . Assume  $0^{\circ}$  inclination angle for the satellites.

Solution:

Given Data

Ground terminal latitude and longitude are:

$$L_e = \text{latitude} = 41.5^{\circ}\text{N} = +41.5$$

$$l_e = \text{longitude} = 87.6^{\circ}\text{W} = -87.6$$

$$H = 0.5\text{km}$$

Now there are two satellite let say Set 1 and Set 2.

longitude for Set 1

$$l_{s1} = 70^{\circ}\text{W} = -70$$

latitude  $l_{s1} = 0^{\circ}$  As inclination angle  $0^{\circ}$



Longitude for Set 2

$$\lambda_{s2} = 135^\circ \text{W} = -135$$

Now to check the reliability of link, we find the elevation angles of the ground station to each satellite.

We know that

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

For finding the elevation angle, we first find the range  $d$ .

So, First of All

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

$$l = \left( \frac{r_e}{\sqrt{1 - l_e^2 \sin^2(L_e)}} + H \right) \cos(L_e)$$

putting the value we get

$$l = \left( \frac{6378.13}{\sqrt{1 - (0.08182)^2 \sin^2(41.5)}} + 0.5 \right) \cos(41.5)$$

$$l = \left( \frac{6378.13}{\sqrt{1 - (6.69 \times 10^{-3}) (0.4390)}} + 0.5 \right) (0.745)$$



$$l = \left( \frac{6378.13}{0.99706} + 0.5 \right) (0.7489)$$

$$l = \left( \frac{6378.13}{0.9985} + 0.5 \right) (0.7489)$$

$$l = (6388.21) (0.7489)$$

$$l = 4784.13 \text{ km}$$

Now next we find Z

$$Z = \left( \frac{R_e (1 - e^2)}{\sqrt{1 - e^2 \sin^2(L_e)}} + H \right) \sin(L_e)$$

$$Z = \left( \frac{6378.13 (1 - 69 \times 10^{-3})}{0.9985} + 0.5 \right) (0.6626)$$

$$Z = \frac{6335.46}{0.9985} + 0.5 \times (0.6626)$$

$$Z = (6344.97 + 0.5) (0.6626)$$

$$Z = (6345.47) (0.6626)$$



$$Z = 4204.51 \text{ km}$$

Now  $R = \sqrt{l^2 + Z^2}$

$$R = \sqrt{(4204.51)^2 + (4784.13)^2}$$

$$R = \sqrt{40565804.2}$$

$$R = 6369.12 \text{ km}$$

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

$$\psi_E = \tan^{-1}\left(\frac{4204.51}{4784.13}\right)$$

$$\psi_E = \tan^{-1}(0.8788)$$

$$\psi_E = 41.31^\circ$$

Now, we find the differential longitude for both satellite  
let say

$$\begin{aligned} B_1 &= l_E - l_{s1} \\ &= -87.6 - (-70) \\ &= -17.6 \end{aligned}$$



Similarly,

$$\begin{aligned} B_2 &= l_E - l_{S_2} \\ &= -87.6 - (-135) \\ &= -87.6 + 135 \\ &= 47.4 \end{aligned}$$

Now we find Ranges

$$d_1 = \sqrt{R^2 + r_s^2 - 2R \cdot r_s \cos(\psi_E) \cos(B_1)}$$

$$d_1 = \sqrt{(6369 \cdot 12)^2 + (42164 \cdot 17)^2 - 2(6369 \cdot 12)(42164 \cdot 17) \cos(41.31^\circ) \cos(17.6^\circ)}$$

$$d_1 = \sqrt{143827607}$$

$$d_1 = 37865.9 \text{ km}$$

And

$$d_2 = \sqrt{R^2 + r_s^2 - 2R \cdot r_s \cos(\psi_E) \cos(B_2)}$$

$$d_2 = \sqrt{(6369 \cdot 12)^2 + (42164 \cdot 17)^2 - 2(6369 \cdot 12)(42164 \cdot 17) \cos(41.31^\circ) \cos(47.4^\circ)}$$



$$d_2 = \sqrt{1542304029}$$

$$d_2 = 39310.35 \text{ km}$$

Now, elevation angle are to be find as :

$$Q_1 = \cos^{-1} \left[ \frac{y_e + \text{base}}{d_1} \right] \sqrt{1 - \cos^2(17.6) \cos^2(41.5)}$$

$$Q_1 = \cos^{-1} \left[ \frac{6378.14 + 35786}{37865.9} \right] \sqrt{1 - (0.9085)(0.5602)}$$

$$Q_1 = \cos^{-1}(1.11353) \sqrt{1 - (0.5376)}$$

$$Q_1 = \cos^{-1}(1.11353) \sqrt{0.46237}$$

$$Q_1 = \cos^{-1}(1.11353)(0.67998)$$

$$Q_1 = \cos^{-1}(0.75718)$$

$$Q_1 = 40.78^\circ$$



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$$Q_2 = \cos^{-1} \left( \frac{8e + base}{d_2} \sqrt{1 - \cos^2(B_2) \cos^2(L_2)} \right)$$

$$Q_2 = \cos^{-1} \left( \frac{6378.14 + 85786}{39310.36} \sqrt{1 - (0.4582)(0.665)} \right)$$

$$Q_2 = \cos^{-1} \left( \frac{42164.16}{39310.36} \sqrt{0.74299} \right)$$

$$Q_2 = \cos^{-1} (1.072596)(0.86197)$$

$$Q_2 = \cos^{-1} (0.92454)$$

$$Q_2 = 22.39^\circ$$

As

$$Q_1 = 40.39^\circ$$

$$Q_2 = 22.39^\circ$$

So, the satellite at  $70^\circ W$  has more reliable link as compare to  $135^\circ W$



Q3: ANSAT receiver consists of a 0.66m diameter antenna, connected to a 4 dB noise figure below noise receiver (LNR) by a cable with a line loss of 1.5 dB. The LNR is connected directly to a downconverter with 10 dB gain and 2800°K noise temperature. The I.F amplifier following the downconverter has a noise figure of 20 dB. The LNR has a gain of 35 dB. The antenna temperature for the receiver was measured as 65°K.

- (a) Calculate the system noise temperature and system noise figure at the receiver antenna terminals.
- (b) The receiver operates at a frequency of 12.5 GHz. What is the C/T for the receiver, assuming a 55% antenna efficiency?



Solution:

Given Data.

Antenna diameter =  $d = 0.66\text{m}$

LNR has noise figure =  $NF = 4\text{dB}$

Cable line loss =  $A = 1.5\text{dB}$

Down converter gain =  $G_{dc} = 10\text{dB}$

" " " " temp =  $T_{dc} = 2800^\circ\text{K}$

IF Amplifier has  $NF = NF = 20\text{dB}$

LNR has gain of =  $G_{LA} = 35\text{dB}$

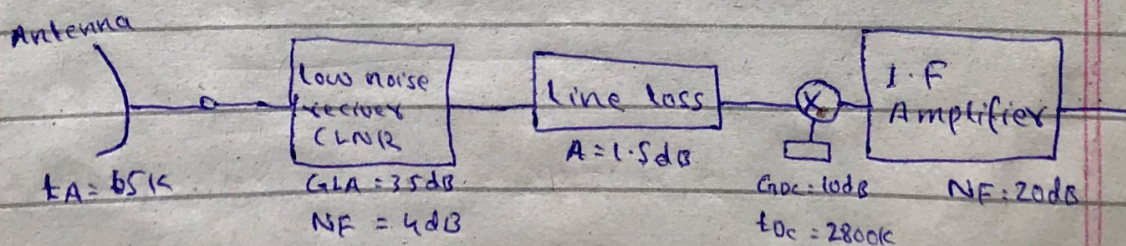
Antenna temp =  $T_A = 65^\circ\text{K}$

1a) Find

$T_s = ?$

$NF_s = ?$

on The basis of The VSAT receiver information and parameter we draw The overall receivers System and respective values as below.





Formula for The Calculation of System noise temperature is :

$$T_s = T_A + T_{LA} + \frac{290(L-1)}{g_{LA}} + \frac{T_{DC}}{\frac{1}{2}g_{LA}} + \frac{T_{IF}}{g_{DC}(K)g_{LA}} \quad \text{--- (1)}$$

Now we find The values of each gain and noise temp.

Antenna :  $T_A = 65^\circ\text{K}$

$$\begin{aligned} \text{LNR} : T_{LA} &= 290(10^{NF/10} - 1) \\ &= 290(10^{4/10} - 1) \\ &= 290(1.51) \end{aligned}$$

$$T_{LA} = 438\text{K}$$

Parameter :  $T_{DC} = 2800^\circ\text{K}$

$$\begin{aligned} \text{iF Amp} : T_{IF} &= 290(10^{NF/10} - 1) = 290(10^{20/10} - 1) \\ &= 290(99) \end{aligned}$$

$$T_{IF} = 28710\text{K}$$

IF Amplifiers :  $T_{IF} = 28710^\circ\text{K}$

$$\begin{aligned} \text{line} : T_{LN} &= 290(L-1) \\ &= 290(10^{1.5/10} - 1) \\ &= 290(0.41) \end{aligned}$$

$$T_{LN} = 119^\circ\text{K}$$



Now we calculate respective gain:

$$\therefore G(\text{dB}) = 10 \log(G)$$

$$G_{LA} = 10^{35/10} = 3162$$

$$G_{OC} = 10^{10/10} = 10$$

$$1/l = \frac{1}{10^{15/10}} = \frac{1}{10^{0.15}} = 0.707$$

Now put all above Calculated values into Eq (1)

$$t_s = 65 + 438 + \frac{119}{3162} + \frac{2800}{(0.707)(3162)} + \frac{287.10}{10(0.707)(3162)}$$

$$t_s = 65 + 438 + 0.038 + 1.252 + 1.286$$

$$t_s = 505.57 \text{ K}$$

we have system noise figure formula as:

$$NF_s = 10 \log \left( 1 + \frac{t_s}{290} \right)$$

$$NF_s = 10 \log \left( 1 + \frac{505.57}{290} \right)$$



$$= 10 \log (1 + 1.743)$$

$$NF_s = 10 \log (2.743)$$

$$NF_s = 4.382 \text{ dB}$$

(B)

Find figure of merit  $= M = G/T = ?$

$$f = 12.5 \text{ GHz}, \eta_A = 0.55, d = 0.66 \text{ m}$$

we first solve for  $G$  in dB as :

$$G_r = 10 \log (109.66 \times f^2 \times d^2 \times \eta_A)$$

$$= 10 \log (109.66 \times (12.5)^2 \times (0.66)^2 \times (0.55))$$

$$= 10 \log (4105.05)$$

$$G_r = 36.13 \text{ dB}$$

then  $T_s$  :

$$T_s = 10 \log (t_s)$$

$$= 10 \log (505.57)$$

$$= 27.03 \text{ dB/K}$$



$$M = C/T = C_{rx} - T_s$$

$$= 36.13 \text{ dB} - 27.03$$

$$\frac{C}{T} = 9.1 \text{ dB/Hz}$$

Q4: The downlink transmission rate for a QPSK modulated SCPC Satellite link is 60 Mbps. The  $E_b/N_0$  at the ground station receiver is 9.5 dB.

- Calculate the  $C/N_0$  for the link.
- Assuming that the uplink noise contribution to the downlink is 1.5 dB, determine the resulting BER for the link.

Sol.

Given Data

$$R_b = \text{bit rate} = 60 \text{ Mbps}$$

$$E_b/N_0 = 9.5 \text{ dB}$$

(a) Find

$$C/N_0 = ?$$

We know that.



$$\frac{E_b}{n_0} = \frac{1}{R_b} (C/n_0) \quad \text{--- ①}$$

convert it from dB:

$$\frac{E_b}{N_0} = 10 \log (C/n_0)$$

$$9.5 = 10 \log (C/n_0)$$

$$C/n_0 = 10^{0.95}$$

$$\boxed{C/n_0 = 8.912}$$

put in eq ①

$$8.912 = \frac{1}{60 \text{ Mbps}} (C/n_0)$$

$$\frac{C}{n_0} = 8.912 \times 60 \times 10^6 \text{ bps}$$

$$\frac{C}{n_0} = 8.912 \times 60 \times 10^6 \text{ bps}$$

$$\frac{C}{n_0} = 534.72 \times 10^6$$

$$\frac{C}{n_0} = 10 \log (534.72 \times 10^6)$$

$$\boxed{\frac{C}{n_0} = 87.282 \text{ dBHz}}$$



(b) As  $\frac{E_b}{N_0} = 9.5 \text{ dB}$  and we have

uplink noise contribution to downlink  
is  $1.5 \text{ dB}$

Now,

$$\frac{E_b}{N_0} = 9.5 \text{ dB} - 1.5 \text{ dB} = 8 \text{ dB}$$

$$\frac{E_b}{N_0} = 10^{0.8}$$

$$\frac{E_b}{N_0} = 6.309$$

Now we know that

$$\text{BER} \approx \frac{e^{-(E_b/N_0)}}{\sqrt{4\pi(E_b/N_0)}}$$

$$\approx \frac{e^{-(6.309)}}{\sqrt{4 \times (3.14) \times (6.309)}}$$

$$\approx \frac{1.819 \times 10^{-3}}{\sqrt{79.28}}$$

$$= \frac{1.819 \times 10^{-3}}{8.904}$$

$$\text{BER} = 2.0429 \times 10^{-4}$$



Q5: An automobile is moving toward a stationary police radar at 65 statute miles per hour. The car's velocity vector is coincident with the axis of radar. The radar transmits on a frequency of 24.150 GHz, in the K-Band. Calculate the frequency of the received echo signal and the Doppler shift?

Sol:

moving automobile has  $V_R = 65$  smph

radar transmit freq  $f_T = 24.150 \text{ GHz}$

$f_d = ?$

$f_R = ?$

first we ~~find~~ convert  $V_R$  from smph to m/s as:

$$\therefore 1 \text{ smph} = 0.44704 \text{ m/s}$$

use Eq 1-3:

$$f_d = 2f_T \frac{V_R}{c}$$

$$= \frac{(2)(24.150 \times 10^9)(29.0576)}{3 \times 10^8}$$



$$f_d = 4678.2736 \text{ Hz}$$

Also we know That

$$f_d = f_R - f_T$$

$$f_R = f_d + f_T$$

$$= 24.150 + 0.000046782736$$

$$f_R = 24.1500046782736 \text{ GHz}$$

Q6: many tactical radars have antenna beamwidth of about  $3^\circ$ . Determine that how far apart in cross-range must two targets at the same range of 24.5 nmi in order to be resolved?

Sol:

$$\text{Antenna beamwidth} = \theta_3 = 3^\circ$$

$$\text{Range from order} = R = 24.5 \text{ nmi} = 45.37 \text{ km}$$

How far apart should be the targets in the cross-range to be resolved?



$$\Delta x = R Q_3 \left( \frac{\pi}{180} \right)$$

$$= 45374 \times 3 \times \frac{\pi}{180}$$

$$\Delta x = 2.374.571$$

$$\Delta x = 2400 \text{ m}$$

if we relate antenna beamwidth with the wavelength of EMW and Antenna length then:

$$Q_3 = \frac{\lambda}{D_{\text{eff}}} \text{ (radians)}$$

$$Q_3 = \frac{\lambda}{D_{\text{eff}}} \left( \frac{180}{\lambda} \right) \text{ (degrees)}$$

' $\lambda$ ' is signal's wavelength  
' $D_{\text{eff}}$ ' is the effective length (meters) of antenna. The  $D_{\text{eff}}$  size is about 0.7 times to its actual size.

So we can use antenna dimensions and the cross-range resolution becomes

$$\Delta x = \frac{R \lambda}{D_{\text{eff}}} \text{ (meter)}$$

