Link System Performance :-

Chapter # 5 :-

⇒ Link Considerations.

* Fixed Antenna Size Link
* " " Gain "
* " " " , fixed antenna size link

⇒ Uplink

* Multiple carrier operation.

⇒ Downlink

⇒ Percent of time performance specifications.

⇒ Link Considerations:

Performance of link can be described by (C/n) and (C/n_o)

So,
$$\frac{c}{n} = \frac{P_r}{n_r} = \frac{P_t g_t g_r \left(\frac{1}{l_{FS} l_o}\right)}{k t_s b_N}$$

and
$$\left(\frac{c}{n_o}\right) = \left(\frac{c}{n}\right) b_N = \frac{P_t g_t g_r \left(\frac{1}{l_{FS} l_o}\right)}{k t_s}$$

Now we put values of g_t, g_r and l_{FS} :

$$g = \eta_A \left(\frac{\pi d}{\lambda}\right)^2$$

$$\left(\frac{c}{n_o}\right) = \frac{P_t \left(\eta_t \frac{4\pi A_t}{\lambda^2}\right)\left(\eta_r \frac{4\pi A_r}{\lambda^2}\right)}{\left(\frac{4\pi r}{\lambda}\right)^2 l_o k t_s}$$

After simplification we get:

$$\left(\frac{c}{n_o}\right) = P_t \eta_t \eta_r \frac{A_t A_r}{\lambda^2 r^2 l_o k t_s}$$

⇒ Fixed Antenna Size link.

Put all fixed values in brackets and we rewrite c/n_o:

$$\left(\frac{c}{n_o}\right) = \left(\frac{\eta_t \eta_r A_t A_r}{l_o k}\right) \frac{P_t}{\lambda^2 r^2 t_s}$$

⇒ Fixed Antenna Gain Link:

$$\left(\frac{c}{n_o}\right) = \frac{P_t g_t g_r}{\left(\frac{4\pi r}{\lambda}\right)^2 l_o k t_s} = \underbrace{\left[\frac{g_t g_r}{(4\pi)^2 l_o k}\right]}_{\text{fixed parameter.}} \frac{P_t \lambda^2}{r^2 t_s}$$

⇒ Fixed Antenna Gain & Antenna Size:

* first quantify satellite coverage requirement.

$$\Omega = \frac{A_s}{d_s^2}$$

Note: $\Omega = 4\pi$ for complete sphere.

* $$g_t \simeq \frac{1}{\Omega} \Rightarrow g_t \simeq \frac{K_1}{\Omega} = \frac{K_1 d_s^2}{A_s}$$

* So c/n_o becomes:

$$\left(\frac{c}{n_o}\right) = \frac{P_t g_t g_r}{l_{FS} l_o k t_s} = \frac{P_t \left(\frac{K_1 r^2}{A_s}\right)\left(\eta_r \frac{4\pi A_r}{\lambda^2}\right)}{\left(\frac{4\pi r}{\lambda}\right)^2 l_o k t_s}$$

$$\left(\frac{c}{n_o}\right) = \left[\frac{K_1 \eta_r A_r}{4\pi A_s l_o k}\right] \frac{P_t}{t_s}$$

Chapter #4 :- PROBLEMS :-

Q. 1:

ⓐ Find gain of parabolic antenna ^{dBi} = ?

$d = 3m$, $f_1 = 6 GHz$, $f_2 = 14 GHz$

we know that for parabolic reflector antenna the gain 'g' is given by:

$$g = \eta_A \left(\frac{\pi d}{\lambda}\right)^2$$

where $\lambda = \frac{c}{f}$

and $c = 3 \times 10^8 m/s$

So, it implies that,

$$g = 109.66 f^2 d^2 \eta_A$$

To find gain in dBi,

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

we also know that $\eta_A = 0.55$, $d = 3m$

So, for f_1 :

$$G = 10 \log (109.66 \times (6)^2 \times (3)^2 \times 0.55)$$

$$= 10 \log (109.66 \times 36 \times 9 \times 0.55)$$

$$= 10 \log (19541.41)$$

$$\boxed{G_1 = 42.9 \, dBi}$$

For f_2 :

$$G = 10 \log (109.66 \times (14)^2 \times (3)^2 \times 0.55)$$

$$= 10 \log (109.66 \times 196 \times 9 \times 0.55)$$

$$= 10 \log (106392.13)$$

$$\boxed{G_2 = 50.26 \, dBi}$$

(b) find gain in dBi = ?, effective area = ?

$d = 30\,m$, $f = 4\,GHz$

we already know that:

$$G = 10 \log(109.66 \times (4)^2 \times (30)^2 \times 0.55)$$

$$= 10 \log(109.66 \times 16 \times 900 \times 0.55)$$

$$= 10 \log(868507.2)$$

$$G = 59.38\ dBi$$

· To find Effective area we use following formula:

$$A_e = \eta_A A$$

where $A = \frac{\pi d^2}{4}$ (for parabolic reflector antenna).

$$A = \frac{(\pi)(30)^2}{4} = \frac{3.14 \times 900}{4}$$

$$A = 706.5\,m^2$$

$$A_e = (0.55)(706.5)$$

$$\boxed{A_e = 388.575\,m^2}$$

(c) Find $A_e = ?$, gain $= 46\,dBi$, $f = 12\,GHz$, $\eta_A = 0.55$

we know, from gain formula:

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

$$46 = 10 \log(109.66 \times (12)^2 \times d^2 \times 0.55)$$

$$46 = 10 \log(8685.072\,d^2)$$

$$4.6 = \log(8685.07\,d^2)$$

Take antilog on both sides:

$$8685.072\,d^2 = 10^{4.6} \Rightarrow d^2 = \frac{10^{4.6}}{8685.072}$$

$$d^2 = 4.5838 \Rightarrow d = 2.14\,m.$$

we also know, $A_e = \eta A$.

where $A = \frac{\pi d^2}{4} = \frac{3.14 \times (2.14)^2}{4} = 3.59\,m^2$

So, $A_e = (0.55)(3.59)$

$$\boxed{A_e = 1.977\,m^2}$$

Q.2: (a) $r = ?$ and $l_{FS} = ?$, $f = 12\,GHz$, GSO link (2)

As the satellite link is a GSO link orbit, so we can take the GSO orbit range as $r = 35900\,km$

We have formula for l_{FS} as:

$$l_{FS} = \left(\frac{40\pi}{3} r f\right)^2$$ where r is in meters and f " in GHz

$$l_{FS} = \left(\frac{(40)(3.14)(35900 \times 1000)(12)}{3}\right)^2$$

$$l_{FS} = (1.8036)^2$$

$$l_{FS} = 3.25 \times 10^2$$

we convert it to dB as:

$$L_{FS} = 10 \log(l_{FS})$$

$$\boxed{L_{FS} = 205.12\,dB}$$

Alternate Method:

$$L_{FS} = 20\log(f) + 20\log(r) + 92.44$$

$$= 20\log(12) + 20\log(35900) + 92.44$$

$$= 21.58 + 91.10 + 92.44$$

$$\boxed{L_{FS} = 205.12\,dB}$$

(b) range, $r = 780\,km$,

Service link freq. $= 1600\,MHz = 1.6\,GHz$.

Feeder " " , $UL = 29.2\,GHz$

" " " , $DL = 19.5\,GHz$

Find $L_{FS} = ?$ $L_{FS(UL)} = ?$, $L_{FS(DL)} = ?$

We know the formula for L_{FS} as:

$$L_{FS} = 20\log(f) + 20\log(r) + 92.44$$

$$= 20\log(1.6) + 20\log(780) + 92.44$$

$$\boxed{L_{FS} = 154.36\ dB}$$

$$L_{FS(UL)} = L_{FS} + 20\log\left(f_u / f_s\right)$$

$$= 154.36 + 20\log\left(\frac{29.24\ GHz}{1.6\ GHz}\right)$$

$$= 154.36 + 20\log(18.275)$$

$$= 154.36 + 25.23$$

$$\boxed{L_{FS(UL)} = 179.59\ dB}$$

$$L_{FS(DL)} = L_{FS} + 20\log\left(f_d / f_s\right)$$

$$= 154.36 + 20\log\left(\frac{19.5\ GHz}{1.6\ GHz}\right)$$

$$= 154.36 + 21.718$$

$$\boxed{L_{FS(DL} = 176.07\ dB}$$

Q.3. Antenna diameter = $d = 0.66\,m$,

LNR has noise figure = $NF = 4\,dB$

Cable line loss = $A = 1.5\,dB$

Down converter gain = $G_{DC} = 10\,dB$

" " temp = $t_{DC} = 2800°K$

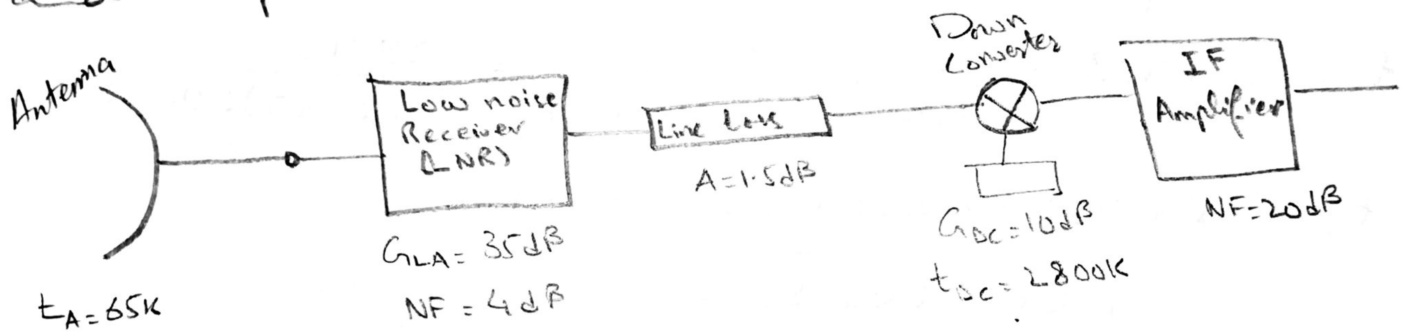
IF amplifier has NF = $NF = 20\,dB$

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

Antenna temp = $t_A = 65°K$

(a) Find $t_s = ?$ $NF_s = ?$

On the basis of the VSAT receiver information and parameters we draw the overall receiver system and respective values as below:



Formula for the calculation of system noise temperature is:

$$t_s = t_A + t_{LA} + \frac{290(l-1)}{g_{LA}} + \frac{t_{DC}}{\frac{1}{l}g_{LA}} + \frac{t_{IF}}{g_{DC}(1/l)\,g_{LA}} \quad \text{—— (1)}$$

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

Antenna: $t_A = 65°K$

LNR: $t_{LA} = 290(10^{NF/10} - 1)$

$= 290(10^{4/10} - 1)$

$= 290(1.51)$

$t_{LA} = 438K$

Downconverter: $t_{DC} = 2800°K$

IF Amp: $t_{IF} = 290(10^{NF/10} - 1) = 290(10^{20/10} - 1)$

$= 290(99) \Rightarrow t_{IF} = 28710K$

IF amplifier: $\quad t_{IF} = 28710°K$

Line $\quad t_{eIN} = 290(l-1)$

$= 290(10^{1.5/10} - 1)$

$= 290(0.41)$

$t_{eIN} = 119°K$

Now we calculate respective gains: $\quad \because G(dB) = 10\log(g)$

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

$g_{DC} = 10^{10/10} = 10$

$1/l = \frac{1}{10^{1.5/10}} = \frac{1}{10^{0.15}} = 0.707$

Now put all above calculated values into eq ①.

$$t_s = 65 + 438 + \frac{119}{3162} + \frac{2800}{(0.707)(3162)} + \frac{28710}{10(0.707)(3162)}$$

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

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

We have system noise figure formula as:

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

$$NF_s = 10\log\left(1 + \frac{505.57}{290}\right) = 10\log(1 + 1.743)$$

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

$$\boxed{NF_s = 4.382\,dB}$$

Q. 3. (b) Find figure of merit $= M = G/T$?

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

we first solve for G in dBi as:

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

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

$= 10 \log(4105.05)$

$G_r = 36.13\ dBi$

Then T_s :

$T_s = 10 \log(t_s)$

$= 10 \log(505.57)$

$= 27.03\ dB/K$

$M = \frac{G}{T} = G_r - T_s$

$= 36.13 dBi - 27.03$

$$\boxed{\frac{G}{T} = 9.1\ dB/k}$$

Q. 4. $R_b =$ bit rate $= 60$ Mbps. , $E_b/N_o = 9.5\ dB$

(a) Find $C/N_o = ?$

we know that: $\frac{e_b}{n_o} = \frac{1}{R_b}\left(\frac{c}{n_o}\right)$ ——— (1)

Convert it from dB:

$\frac{E_b}{N_o} = 10 \log\left(\frac{e_b}{n_o}\right)$

$9.5 = 10 \log\left(\frac{e_b}{n_o}\right)$ => $e_b/n_o = 10^{0.95}$

$\frac{e_b}{n_o} = 8.912$

Put in eq (1)

$$8.912 = \frac{1}{60\,\text{mbps}}\left(\frac{c}{n_o}\right)$$

$$\frac{c}{n_o} = 8.912 \times 60 \times 10^6 \text{ bps}$$

$$\frac{c}{n_o} = 534.72 \times 10^6$$

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

$$\boxed{\frac{C}{N_o} = 87.28 \text{ dBHz}}$$

(b) As $\frac{E_b}{N_o} = 9.5$ dB and we have Uplink noise contribution to downlink is 1.5 dB.

Now, $\frac{E_b}{N_o} = 9.5\text{dB} - 1.5\text{dB} = 8\text{dB}$

$$\frac{e_b}{n_o} = 10^{0.8}$$

$$\frac{e_b}{n_o} = 6.309$$

Now we know that: (Page 366)

$$BER \simeq \frac{e^{-(e_b/n_o)}}{\sqrt{4\pi(e_b/n_o)}}$$

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

$$\simeq \frac{1.819 \times 10^{-3}}{\sqrt{79.28}} = \frac{1.819 \times 10^{-3}}{8.904}$$

$$\boxed{BER \simeq 2.0429 \times 10^{-4}}$$