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GROUP 6 : ANALOGUE TRANSMISSION PROJECT 2021

TOPIC: QoS DESIGN OF LEO SATELLITE RECEIVER

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PART ONE:

- **Find the g_3 uplink without coding**

$(\frac{C}{N})_{uplink}$ = EIRP + (Gr – Ts) + M + 228.6 – (Lp + Lx + BRF)

- $g_r = \eta\,(\frac{\pi D}{\lambda})^2$ => $Gr = 10\log[\eta\,(\frac{\pi D}{\lambda})^2]$ with $\lambda = \frac{C}{f}$

  $Gr = 10\log\,[\eta\,(\frac{\pi f D}{c})^2]$

  $G_R = 10\log\,[\frac{60.5}{100}(\frac{\pi\ x\ 5.79\ x\ 10^9\ x\ 2.22}{3\ x\ 10^8})^2]$ = **40.39875687 dB**

- $(\frac{C}{N})_u$ = EIRP + (Gr – Ts) + M + 228.6 – (Lp + Lx + BRF)

  Ts = EIRP + GR – $(\frac{C}{N})_{uplink}$ + M+ 228.6 – (Lp + Lx + BRF)

$Lp = 92.44 + 20Log_{10}\,(f_{GHz}) + 20log_{10}\,(d_{km})$

$= 92.44 + 20log_{10}\,(5.79) + 20log_{10}\,(1107)$

Lp = 168.57652369212 dB

Lx = rain attenuation + atmospheric losses + poynting losses + polarization losses + other losses

Lx = 2.95 + 9.095 + 4.47 + 3.93 + 7.75

Lx = 28.195 dB

$BRF = 10log_{10}\,(brf) = 10log_{10}\,(20 \times 10^6)$

BRF = 73.01029996 dB

Ts = 48.975 +40.39875687 – 15.75 +3 +228.6 – (168.57652369212 + 28.195 + 73.01029996)

Ts = 35.44193322 dBK

$Ts = 10^{3.544193322}$ K

Ts = 3501.00976420312 K

$Ts = (Fs – 1)T_0$

$Fs = 1 + \frac{Ts}{T_0}$

$$Fs = 1 + \frac{3501.00976420312}{290}$$

Fs = 13.07244746277

By taking:

1 => Antenna

2 => Feeder

3=> RF AMP

4 => RF BPF

5 => Mixer 1

6 => IF BPF1

7 => IF AMP1

8 => Mixer 2

9 => IF BPF2

10 => IF AMP2

11 => DEMOD

12 => LPF

$$Fs = F_1 + \frac{F_2-1}{g_1} + \frac{F_3-1}{g_1\, g_2} + \frac{F_4-1}{g_1\, g_2 g_3} + \frac{F_5-1}{g_1\, g_2 g_3\; g_4} + \frac{F_6-1}{g_1\, g_2 g_3\; g_4\, g_5} + \frac{F_7-1}{g_1\, g_2 g_3\; g_4\, g_5 g_6} + \frac{F_8-1}{g_1\, g_2 g_3\; g_4\, g_5 g_6 g_7} + \frac{F_9-1}{g_1\, g_2 g_3\; g_4\, g_5 g_6 g_7 g_8} + \frac{F_{10}-1}{g_1\, g_2 g_3\; g_4\, g_5 g_6 g_7 g_8 g_9} + \frac{F_{11}-1}{g_1\, g_2 g_3\; g_4\, g_5 g_6 g_7 g_8 g_9 g_{10}} + \frac{F_{12}-1}{g_1\, g_2 g_3\; g_4\, g_5 g_6 g_7 g_8 g_9 g_{10} g_{11}}$$

- $G_1 = 1$
- 2 ; 4 ; 5 ; 6 ; 8 ; 9 ; 11; 12 are passive components
  So their gain $g = \frac{1}{L}$ and their F = L

$T_1 = (F_1 - 1)\, T_0 \Rightarrow F_1 = 1 + \frac{T_1}{T_0}$

$$Fs = F_1 + L_2 - 1 + (F_3 - 1)\, L2 + \frac{(L_4-1)L_2}{g_3} + \frac{(L_5-1)L_2 \text{x}\, L_4}{g_3} + \frac{(L_6-1)L_2 \text{x}\, L_4 \text{ x } L_5}{g_3} + \frac{(F_7-1)L_2 \text{x}\, L_4 \text{ x } L_5 \text{x}\, L_6}{g_3} + \frac{(L_8-1)L_2 \text{x}\, L_4 \text{ x } L_5 \text{x}\, L_6}{g_3 g_7} + \frac{(L_9-1)L_2 \text{x}\, L_4 \text{ x } L_5 \text{x}\, L_6 \text{x}\, L_8}{g_3 g_7} + \frac{(F_{10}-1)L_2 \text{x}\, L_4 \text{ x } L_5 \text{x}\, L_6 \text{x}\, L_8 \text{x}\, L_9}{g_3 g_7} + \frac{(L_{11}-1)L_2 \text{x}\, L_4 \text{ x } L_5 \text{x}\, L_6 \text{x}\, L_8 \text{x}\, L_9}{g_3 g_7 g_{10}} + \frac{(F_{12}-1)L_2 \text{x}\, L_4 \text{ x } L_5 \text{x}\, L_6 \text{x}\, L_8 \text{x}\, L_9 \text{ x } L_{11}}{g_3 g_7 g_{10}}$$

With:

L2 = 5.045

L2 x L4 = 5.045 x $10^{0.778}$

L2 x L4 x L5 = 5.045 x $10^{1.465}$

$L2 \times L4 \times L5 \times L6 = 5.045 \times 10^{2.262}$

$L2 \times L4 \times L5 \times L6 \times L8 = 5.045 \times 10^{3.068}$

$L2 \times L4 \times L5 \times L6 \times L8 \times L9 = 5.045 \times 10^{3.856}$

$L2 \times L4 \times L5 \times L6 \times L8 \times L9 \times L11 = 5.045 \times 10^{4.981}$

$g_7 = 10^{2.2}$

$g_{10} = 10^{2.025}$

$g_7 \times g_{10} = 10^{4.225}$

$$Fs = F_1 + L_2F_3 - 1 + \frac{5.045}{g_3}\Big[(L_4 - 1) + (L5 - 1)\,10^{0.778} + (L_6 - 1) \times 10^{1.465} + (F_7 - 1) \times 10^{2.262} + (L_8 - 1) \times 10^{2.262-2.025} + (L9 - 1) \times 10^{3.068-2.025} + (F_{10} - 1) \times 10^{3.856-2.025} + (L_{11} - 1) \times 10^{3.856-4.225} + (F_{12} - 1) \times 10^{4.981-4.225}\Big]$$

$$g_3 = \frac{5.045}{Fs - \frac{T1}{T0} - 5.045F3}\Big[(L_4 - 1) + (L_5 - 1) \times 10^{0.778} + (L_6 - 1) \times 10^{1.465} + (F_7 - 1) \times 10^{2.262} + (L_8 - 1) \times 10^{0.237} + (L_9 - 1) \times 10^{1.043} + (F_{10} - 1) \times 10^{1.043} + (L_{11} - 1) \times 10^{-0.369} + (F_{12} - 1) \times 10^{0.756}\Big]$$

$g_3 = 7081.74503826386$

$G_3 = 10\text{Log}_{10}(g_3) = 10\log(7081.74503826386)$

$$\boxed{G_3 = 38.5014 \text{ dB}}$$

- <u>Find G_3 with coding</u>

16 QAM ⇔ 2^4 QAM => n = 4

$R_b = \frac{n \times brf}{1+\alpha} = \frac{4 \times 20}{1.22}$ Mbps

$$\boxed{R_b = \frac{4000}{61} \text{ Mbps}}$$

We have $\frac{eb}{n_0} = (\frac{C}{n}) \times \frac{brf}{R_b}$ with Brf = 20 MHz and $R_b = \frac{4000}{61}$ Mbps

So $(\frac{Eb}{N0})$ uncoded = $(\frac{C}{N})$ uncoded + $10\log_{10}(\frac{brf}{Rb})$

$(\frac{Eb}{N0})$ uncoded = 15.75+ $10\log_{10}(\frac{61 \times 20}{4000})$

$(\frac{Eb}{N0})$ uncoded**= 10.59299843 dB**

Then we get BER by:

$$BER = 4(1-\frac{1}{\sqrt{M}})\ Q\left[\sqrt{\frac{3\log_2 M}{M-1}(\frac{eb}{n0})\text{ uncoded}}\right]$$ and M = 16 and

$$\left(\frac{eb}{n0}\right)\text{uncoded} = 10^{\frac{(\frac{Eb}{N0})\text{ uncoded}}{10}}$$

$$BER = 3Q\left(\sqrt{\frac{4}{5}(\frac{eb}{n0})\text{ uncoded}}\right)$$

BER=3Q (3.02827223706)

$BER_{uncoded}$= 0.00368934607

$$G_c = 20log_{10}\left[\text{erfc}^{-1}(2BER_{coded})\right] - 20log_{10}\left[\text{erfc}^{-1}(2BER_{uncoded})\right] + 10log_{10}(r_c)$$

$$G_c = 20log_{10}\left[5.754261031212999990263\right] - 20log_{10}\left[1.894516994431603057406\right] + 10log_{10}(\frac{7}{8})$$

G_c = 9.06990160145 dB

We have $(\frac{Eb}{N_0})$ coded = $(\frac{Eb}{N_0})$ uncoded – G_c, in DB, then we get it in linear value by :

$\left(\frac{Eb}{N_0}\right) coded = \left(\frac{Eb}{N_0}\right) uncoded - \text{Gc}$

$\left(\frac{Eb}{N_0}\right) coded = 10.59299843 - 9.06990160145$

$\boxed{\left(\frac{Eb}{N_0}\right) \boldsymbol{coded} = \mathbf{1.52309682855\ dB}}$

$R_{bcoded} = R_b \times r_c$

$\boxed{R_{bcoded} = \mathbf{57.37704875\ Mbps}}$

$\left(\frac{C}{N}\right)$ coded = $\left(\frac{Eb}{N_0}\right) coded + 10\log\left(\frac{(R_b)coded}{B_n}\right)$

$\left(\frac{C}{N}\right)$ coded = $1.52309682855 + 10\log\left(\frac{57.37704875}{20}\right)$

$\boxed{\left(\frac{C}{N}\right) \text{coded} = \mathbf{6.10017893273\ dB}}$

$\left(\frac{C}{N}\right)$ coded = EIRP + $\left(\frac{G}{T}\right)$ coded + 228.6 – L_p – L_x - 10log (Brf) +M

Ts = EIRP + GR – $\left(\frac{C}{N}\right)$ coded + M+ 228.6 – (Lp + Lx + BRF)

Ts = 48.975 + 40.39875687 – 6.10017893273 + 3 + 228.6 – (168.57652369212 + 28.195 + 73.01029996)

Ts = 45.09175428515 dBK

Ts = $10^{4.509175428515}$ K

Ts = 32297.98500096295 K

Ts = (Fs – 1) T0

Fs = 1 + $\frac{Ts}{T_0}$

Fs = 1 + $\frac{32297.98500096295}{290}$

Fs = 112.37236207229

$g_3 = \frac{5.045}{Fs - \frac{T1}{T0} - 5.045F3}\Big[(L_4 - 1) + (L_5 - 1) \times 10^{0.778} + (L_6 - 1) \times 10^{1.465} + (F_7 - 1) \times 10^{2.262} + (L_8 - 1) \times 10^{0.237} + (L_9 - 1) \times 10^{1.043} + (F_{10} - 1) \times 10^{1.831} + (L_{11} - 1) \times 10^{-0.369} + (F_{12} - 1) \times 10^{0.756}\Big]$

$g_3 = 43.37332905242$

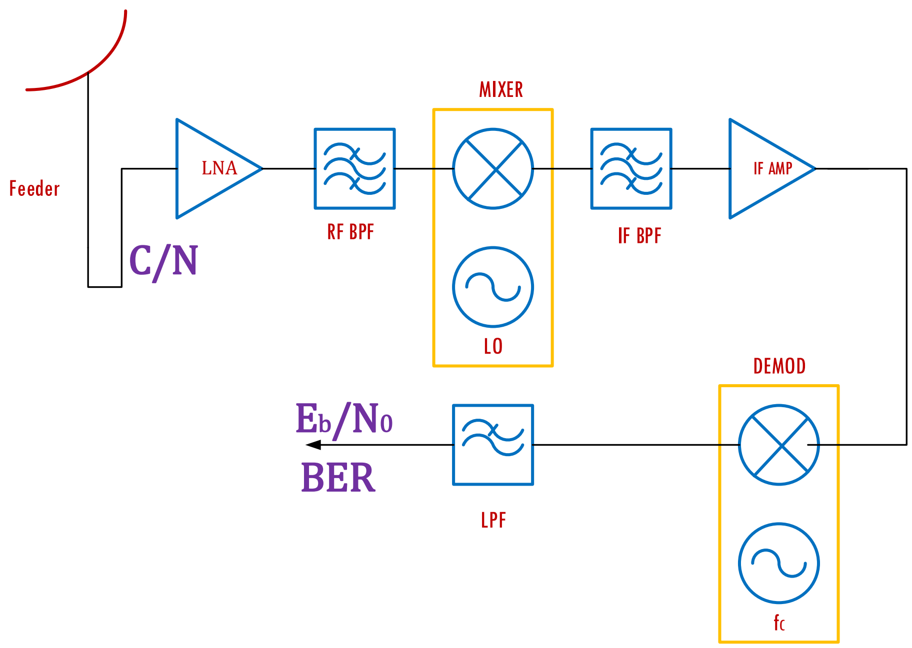
$G_3 = 10\mathrm{Log}_{10}(g_3) = 10\log(43.37332905242)$

$\boxed{G_3 = 16.3722 \text{ dB}}$

CONCLUSION

The gain of the RF Amplifier decreases when a coding channel is used. So with coding we can low the noise figure efficiently even with a low RF Amplifier gain

PART TWO :



1) Using the figure below and the information in table 1, calculate the system ***Noise Temperature.***

By taking:

1 => Antenna

2 => LNA

3 => RF BPF

4 => Mixer

5 => IF BPF

6 => IF AMP

7 => DEMOD

8 => LPF

$$F_s = F_1 + \frac{F_2-1}{g_1} + \frac{F_3-1}{g_1\, g_2} + \frac{F_4-1}{g_1\, g_2 g_3} + \frac{F_5-1}{g_1\, g_2 g_3\; g_4} + \frac{F_6-1}{g_1\, g_2 g_3\; g_4\, g_5} + \frac{F_7-1}{g_1\, g_2 g_3\; g_4\, g_5 g_6} + \frac{F_8-1}{g_1\, g_2 g_3\; g_4\, g_5 g_6 g_7}$$

With: $g_1 = 1$

The components 3; 4; 5; 7 and 8 are passive so their $g = \frac{1}{L}$ and their F=L

So

$$:F_s = F_1 + \frac{F_2-1}{1} + \frac{L_3-1}{1\,.\,g_2} + \frac{L_3(L_4-1)}{1\,.\,g_2} + \frac{L_4L_3(L_5-1)}{1\,.\,g_2} + \frac{L_5L_4L_3(F_6-1)}{1\,.\,g_2} + \frac{L_5L_4L_3(L_7-1)}{g_2\ g_6} + \frac{L_7L_5L_4L_3(L_8-1)}{g_2\ g_6}$$

With:

$$L_3 = 10^{0.525}$$

$$L_4L_3 = 10^{0.525} \times 10^{0.737} = 10^{1.262}$$

$$L_5L_4L_3 = 10^{1.262} \times 10^{0.595} = 10^{1.857}$$

$$L_7L_5L_4L_3 = 10^{1.857} \times 10^{1.203} = 10^{3.06}$$

$$g_2 = 10^3$$

$$g_2\ g_6 = 10^3 \times 10^{2.5} = 10^{5.5}$$

$$F_s = F_1 + F_2 - 1 + \frac{1}{g_2}\left[L_3 - 1 + L_3(L_4-1) + L_4L_3(L_5-1) + L_5L_4L_3(F_6-1)\right] + \frac{1}{g_2\ g_6}\left[\,L_5L_4L_3(L_7-1) + L_7L_5L_4L_3(L_8-1)\right]$$

Therefore:

$$F_s = 1 + \frac{606.1}{290} + 1.98 - 1 + \frac{1}{10^3}\left[\ 10^{0.525} - 1 + 10^{0.525}(10^{0.737}-1) + 10^{1.262}\left(10^{0.595}-1\right) + 10^{1.857}\,(2.75-1)\right] + \frac{1}{10^{5.5}}\left[10^{1.857}\,(10^{1.203}-1) + 10^{3.06}(10^{0.555}-1)\right]$$

Fs = 4.27965262699

That gives us $T_s = (F_s - 1)\,T_o = (4.27965262699 - 1) \times 290$

$$\boxed{T_s = 951.0992618271\ \text{K}} \quad \text{so} \quad \boxed{T_s = 29.78225844607\ \text{dBK}}$$

2) Using the information in tables 1 and 2, find the $\left(\frac{G}{T}\right)$ of the satellite receiver, when no Channel ***coding Scheme*** is applied.

$$\left(\frac{C}{N}\right) = \text{EIRP} + G_R - T_s + M + 228.6 - L_p - L_X - 10log_{10}(brf)$$

$$G_R = \left(\frac{C}{N}\right) + T_s + 10Log_{10}(brf) - \text{EIRP} - 228.6 + (L_X + L_p) - M$$

$$L_p = 92.44 + 20\,Log_{10}(1027) + 20Log_{10}(2.4)$$

$$\mathbf{L_p = 160.27563370618\ dB}$$

L_X = rain attenuation + atmospheric loss + poynting loss + polarization loss + other loss

L_X = 26.37 dB

$$\left(\frac{c}{n}\right)_D = \frac{1}{\frac{1}{\left(\frac{c}{n}\right)_T} - \frac{1}{\left(\frac{c}{n}\right)_U}} = \frac{1}{\frac{1}{10^{1.225}} - \frac{1}{10^{1.575}}} = 30.34075972$$

$$\boxed{\left(\frac{C}{N}\right)_D = 14.82\ \text{dB}}$$

$$G_{R\ uncoded} = 14.82 + 29.78225844607 + 160.27563370618 + 26.37 + 10Log_{10}(6 \times 10^6) - 39.685 - 228.6 - 3$$

$$\boxed{G_{R\ uncoded} = 27.74440465592\ \text{dB}}$$

$$g_r = 10^{\frac{GR\ uncoded}{10}}$$

$$\boxed{g_{r\ uncoded} = 594.89520112628}$$

3) The uncoded ***Data Rate*** depends on the ***Digital Modulation*** type and given as:

$$R_b = \frac{B_n \times (Number\ of\ bits/symbol)}{(1+\alpha)(Hz.s/symbol)} \rightarrow bits/s$$

Where B_n and α are the ***Noise Bandwidth*** in Hz and the ***Roll-off factor***, respectively,

Find the data rate in Mbps.

$R_b = \frac{B_n * N}{1+\propto} = \frac{6Mhz * N}{1+0{,}25}$

Where M = 2^N => $\boxed{N = 4 \text{ bits /Symbol}}$

$R_b = \frac{6*4}{1{,}25}$

$\boxed{R_b = \frac{96}{5} \text{ Mbps}}$

4) Find $\left(\frac{e_b}{n_0}\right)$ at the output of the digital demodulator and derive the ***BER*** (***probability of error***) at the output of the digital demodulator

We have $\frac{eb}{n_0} = \left(\frac{C}{n}\right) \times \frac{brf}{R_b}$ with b_{rf} = 6 Mhz and $R_b = \frac{96}{5}\ Mbps$

So $\left(\frac{Eb}{N_0}\right) = \left(\frac{C}{N}\right) + 10Log_{10}\left(\frac{brf}{R_b}\right)$

$\left(\frac{Eb}{N_0}\right) = 14.82 + 10Log_{10}\left(\frac{5 \times 6}{96}\right)$

$$\boxed{\left(\frac{Eb}{N_0}\right)_{uncoded} = 9.7685002168 \text{ dB}}$$

Then we get BER by:

BER = $4\left(1-\frac{1}{M}\right) Q\left[\sqrt{\frac{3log_2M}{M-1}\left(\frac{E_b}{N_0}\right)}\right]$ and M = 16 and $\left(\frac{e_b}{n_0}\right)_{uncoded} = 10^{\frac{\left(\frac{E_b}{N_0}\right)uncoded}{10}}$

BER = $3Q\left(\sqrt{\frac{4}{5}\left(\frac{e_b}{n_0}\right)_{uncoded}}\right)$

BER=3Q(2.75403848203)

$$\boxed{BER_{uncoded} = 0.00882972696}$$

5) Find the ***Coding Gain*** using the result obtained in 4) and the ***Required BER*** in table 2.

$$Gc = 20log_{10}\left[\text{erfc}^{-1}(2BER_{coded})\right] - 20log_{10}\left[\text{erfc}^{-1}(2BER_{uncoded})\right] + 10log_{10}(r_c)$$

$$Gc=20log_{10}\left[5.30396815847701830236 4\right]-$$

$$20log_{10}\left[1.67773962970668356076 2\right] + 10log_{10}\left(\frac{5}{6}\right)$$

Gc = 9.20571444178 dB

6) Calculate the new value of $\left(\frac{e_b}{n_0}\right)$ at the output of the coder.

We have $\left(\frac{Eb}{N_0}\right)_{coded} = \left(\frac{Eb}{N_0}\right)_{uncoded} - G_c$, in DB, then we

get it in linear value by :

$$\left(\frac{eb}{n_0}\right)_{coded} = 10^{\frac{\left(\frac{Eb}{N_0}\right)coded}{10}} = 10^{\frac{\left(\frac{Eb}{N_0}\right)uncoded - Gc}{10}} = 10^{\frac{9.7685002168 - 9.20571444178}{10}}$$

$\left(\frac{eb}{n_0}\right)_{coded}$ **= 1.13835724912**

7) Find the data rate at the output of the coder

$R_{bcoded} = R_b \times r_c$

R_{bcoded} = 16 Mbps

8) Derive the value of the coded $\left(\frac{c}{n}\right)$,

$$\left(\frac{c}{n}\right)_{coded} = \left(\frac{eb}{n0}\right)_{coded} \times \frac{(R_b)coded}{B_n} = 1.13835724912 \times \frac{16}{6}$$

$\boxed{(\frac{c}{n})_{coded} = 3.03561933099}$

9) let find the new $(\frac{G}{T})$

$(\frac{C}{N})_{coded}$ = EIRP + $(\frac{G}{T})_{coded}$ + 228.6 – L_p – L_x - 10log (Brf) +M

So G_r = $(\frac{C}{N})_{coded}$ + T_s +-EIRP - 228.6 + L_p + L_x + 10log (Brf) - M

= 10log (3.03561933099) + 29.78225844607 - 39.685 – 228.6 +160.27563370618 + 26.37 +10log (6 x10^6) -3

$\boxed{G_{r\ coded} = 17.74687775367 \text{ dB}}$

$g_r=10^{\frac{17.74687775367}{10}}$

$\boxed{g_{r\ coded} = 59.52340617434}$

10) With the gain of antenna parabolic

$$g=\frac{4\pi\eta a_{phy}}{\lambda^2} = (\frac{\pi D}{\lambda})^2\eta$$

i) Let show that D = $\sqrt{\frac{4a_{phy}}{\pi}}$

According to the formula of g, we have

$\frac{4\pi\eta a_{phy}}{\lambda^2} = (\frac{\pi D}{\lambda})^2\eta$ then we get

$(\frac{\pi D}{\lambda})^2 = \frac{4\pi\eta a_{phy}}{\lambda^2} \times \frac{1}{\eta}$; $(\pi D)^2 \times \frac{4\pi\eta a_{phy}}{\lambda^2} \times \frac{1}{\eta} \times \lambda^2$

$= 4a_{phy}\pi$

$D^2 = \frac{4a_{phy}}{\pi}$ so $D = \sqrt{\frac{4a_{phy}}{\pi}}$

$$D = \sqrt{\frac{\lambda^2 g}{\pi^2 \eta}} = \frac{\lambda}{\pi}\sqrt{\frac{g_{uncoded}}{\eta}} = \frac{c}{\pi f}\sqrt{\frac{g_{uncoded}}{\eta}}$$

$$D = \frac{3 \text{ x } 10^8}{\pi \text{ x } 2.4 \text{ x } 10^9}\sqrt{\frac{594.89520112628}{0.6075}}$$

So $\boxed{D = 1.24510859758m}$

ii) Let calculate D after coding

$$D = \frac{c}{\pi f}\sqrt{\frac{g_{coded}}{\eta}}$$

$$D = \frac{3 \text{ x } 10^8}{\pi \text{ x } 2.4 \text{ x } 10^9}\sqrt{\frac{59.52340617434}{0.6075}}$$

$$\boxed{D = 0.39385003361 \text{ m}}$$

11)

CONCLUSION

The diameter of the antenna without coding is 1.24510859758 m which is difficult to achieve even impossible with small receivers such as mobile phone laptop.

The code allowed to go from a diameter of 1.24510859758 m to a one of 0.39385003361 m which more practical. So the code make it possible to carry out the antenna.