

Exercices de math

MATH exercices en rapport avec la page 6

$$1) \quad (5, -12) \quad \text{ou} \quad 5 - 12i$$

$$1.1 \quad \Rightarrow \quad (5, -12) (x, y) = (1, 0)$$

Ou

$$1.2 \quad \Rightarrow \quad (5 - 12i) (x + yi) = 1 + 0i$$

$$\begin{aligned} 1.1 \quad \Rightarrow \quad (a, b) (a', b') &= (aa' - bb', ab' - a'b) \\ &= (5X + 12Y, 5Y - 12X) \\ &= (1, 0) \end{aligned}$$

$$5X + 12Y = 1$$

$$5Y - 12X = 0 \quad \Rightarrow \quad Y = 12X / 5$$

$$5X + \frac{12 * 12X}{5} = 1$$

$$\frac{25X + 144X}{5} = 1 \quad \Rightarrow \quad 169X / 5 = 1$$

$$\Rightarrow \quad x = 5 / 169 \quad \Rightarrow \quad y = 12 / 169$$

$$\left(\frac{a}{a^2 + b^2}, \frac{-b}{a^2 + b^2} \right)$$

$$\Rightarrow \quad a = 5 \quad \text{et} \quad b = -12$$

$$\left(\frac{5}{5^2 + (-12)^2}, \frac{12}{5^2 + (-12)^2} \right)$$

$$\Rightarrow \quad (5 / 169 , 12 / 169)$$

Vérification

$$(5 , -12) (5 / 169 , 12 / 169) = (1 , 0)$$

2) (4 , 0) ou 4

$$(4 , 0) (X , Y) = (1 , 0)$$

$$(4 X , 4 Y) = (1 , 0)$$

$$4 X = 1 \Rightarrow X = 1/4$$

$$4 Y = 0 \Rightarrow Y = 0$$

$$\Rightarrow (1 / 4 , 0)$$

3) (0 , - 2) ou - 2 i

$$(0 , - 2) (X , Y) = 1 = (1 , 0)$$

$$(2 Y , - 2 X)$$

$$2 Y = 1 \Rightarrow Y = 1/2$$

$$- 2 X = 0 \Rightarrow X = 0 \Rightarrow (0 , \frac{1}{2})$$

Vérification (au choix)

$$3.1. \left(\frac{a}{a^2 + b^2} , \frac{-b}{a^2 + b^2} \right) = (0 , 2/4) = (0 , 1/2)$$

$$3.2. (0 - 2 i) (X + Y i) = 1$$

$$2 Y - 2 X i = 1 + 0 i$$

$$- 2 X = 0 \Rightarrow x = 0$$

$$0 + 1/2 i = 1/2 i \Rightarrow Y = 1/2$$

$$4) \quad (3/25, -4/25) \quad \text{ou} \quad 3/25 - 4/25 i$$

$$(4/25, -4/25) (X, Y) = (1, 0)$$

$$(1) \Rightarrow 3/25 X + 4/25 Y = 1$$

$$(2) \Rightarrow 3/25 Y - 4/25 X = 0$$

$$(2) \Rightarrow 3/25 Y = 4/25 X$$

$$(2) \Rightarrow Y = 4/3 X$$

$$(1) \Rightarrow \frac{3}{25} X + \frac{4}{25} * \frac{4}{3} X = 1 \Rightarrow \frac{9}{75} * \frac{16 X}{75} = 1$$

$$\Rightarrow 125 X / 75 = 1 \Rightarrow X = 3$$

La solution du 5 : $(0, -1)$

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3.2. Calculer les expressions suivantes :

$$1) \quad (2 + i)^2 = 4 + 4i - 1 = 3 + 4i$$

$$2) \quad (5 - 7i) - (2 + 4i) = 3 - 11i$$

$$3) \quad (1 + 3i) * 2i = 2i + 6i^2 = 2i - 6$$

$$4) \quad ((\sqrt{6} + 5i)^2 * (2 - 7i)) = (6 + 10\sqrt{6} - 25)(2 - 7i) \\ = -38 + 133i + 20\sqrt{6}i + 70\sqrt{6} = -38 + 70\sqrt{6} + (133 + 2\sqrt{6})i$$

$$5) \quad 4i * (-2i) * (2 + 3i) = (16i + 8)(2 + 3i) = 32i + 46 - 48 + 24i \\ = 8(-4 + 7i)$$

3.3. Calculer les expressions suivantes : (il y a juste les réponses)

1)

$$\Rightarrow \frac{(1+i)(1+i)}{(1-i) * (1+i)} + \frac{(1-i)(1-i)}{(1-i) * (1-i)}$$

$$\Rightarrow \frac{(1+i)^2}{2} + \frac{(1-i)^2}{2}$$

$$\Rightarrow \frac{1+2i-1+1-2i-1}{2} = 0$$

2)

$$\Rightarrow \frac{1+2i-1}{1-2i-1} = -\frac{2i}{2i} = -1$$

3)

$$\begin{aligned} \Rightarrow & \frac{i(2-5i)}{(2+5i)*(2-5i)} + \frac{i*(2+5i)}{(2-5i)*(2+5i)} \\ = & \frac{2i+5+2i-5}{4+25} = \frac{4i}{29} \end{aligned}$$

4)

$$\begin{aligned} \Rightarrow & \frac{(\sqrt{5}+i)^2}{(\sqrt{5}-i)(\sqrt{5}+i)} = \frac{5+2\sqrt{5}*i-1}{5+1} \\ = & \frac{4+2\sqrt{5}i}{6} = \frac{2+\sqrt{5}i}{3} \end{aligned}$$

5)

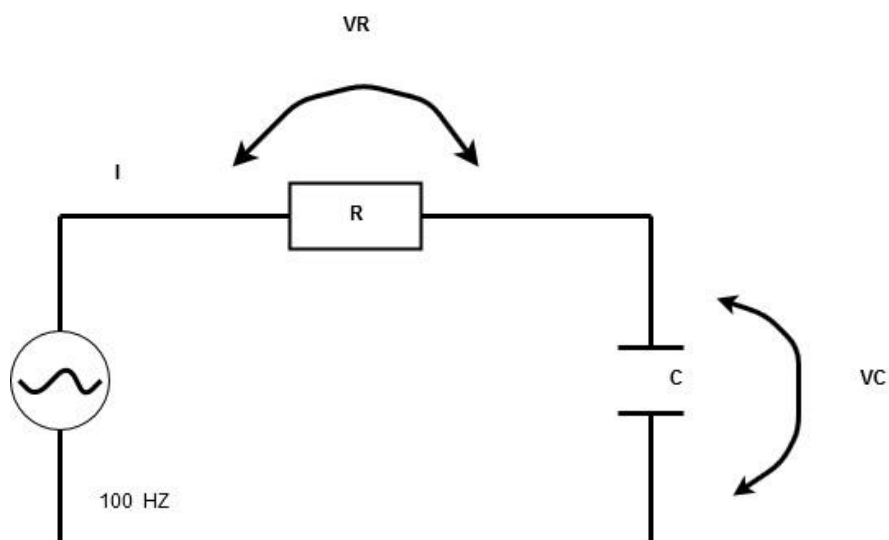
$$\begin{aligned} & \frac{\cos \theta - i \sin \theta}{(\cos \theta + i \sin \theta)(\cos \theta - i \sin \theta)} = \frac{\cos \theta - i \sin \theta}{\cos^2 \theta + \sin^2 \theta} \\ = & \cos \theta - i \sin \theta \end{aligned}$$

6)

$$\frac{1}{\cos \theta - i \sin \theta} = \cos \theta + i \sin \theta$$

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1) Calculer : Z ; I ; V_C ; V_R



$$Z = R + jX = ?$$

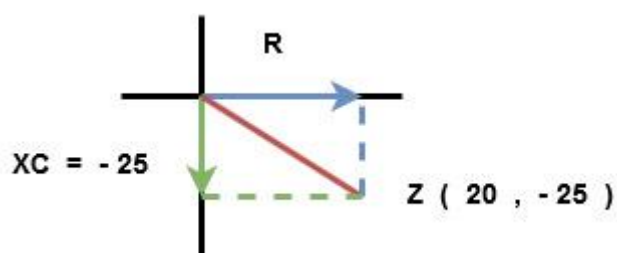
$$C = 64 \text{ nF}$$

$$R = 20 \, \Omega$$

$$Z = 20 + jX = ?$$

$$X_C = 1 / j\omega C = \frac{1}{j 2\pi * 100 * (64 * 10^{-6})} = -j 25 \, \Omega = 25^{-90^\circ}$$

$$Z = 20 + (-25j) \, \Omega$$



$$|Z| = \sqrt{20^2 + (-25)^2} = 32 \text{ n}$$

$$\theta = \arctg \frac{-25}{20} = -51,34^\circ$$

$$Z = 32^{-51,34}$$

$$I = ?$$

$$U = Z * I$$

$$I = \frac{U}{Z} = \frac{10^{0^\circ}}{32^{-51,34^\circ}} = 0,3125^{51,34^\circ}$$

$$V_c = X_C * I = 25^{-90^\circ} * 0,3125^{51,34^\circ} = 7,8125^{-38,66^\circ}$$

$$V_R = R * I = 20^{0^\circ} * 0,3125^{51,34^\circ}$$

Vérification :

$$V = V_R + V_C$$

$$V = 6,25^{51,34} + 7,8125$$

$$V_R = 6,25^{51,34} = a + b j \quad \Rightarrow \quad a = 6,25 * \cos 51,34$$

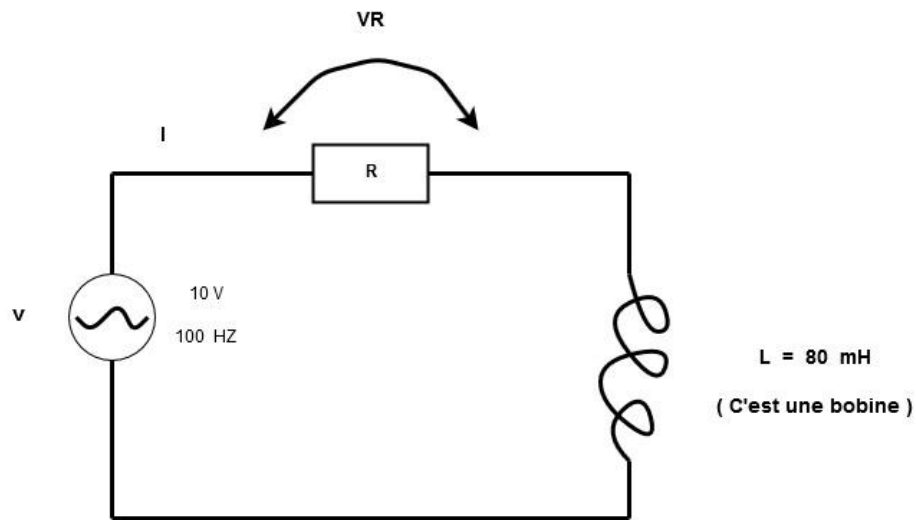
$$\Rightarrow \quad b = 6,25 * \sin 51,34$$

$$\Rightarrow \quad 3,9 + 4,9 j$$

$$V = 10 = V_R + V_C$$

$$\Rightarrow \quad (3,9 + 4,9 j) + (6,1 - 4,9 j) = 10 + 0 j \text{ V}$$

2) Calculer : Z ; I ; V_C ; V_R



$$Z = R + j X_L$$

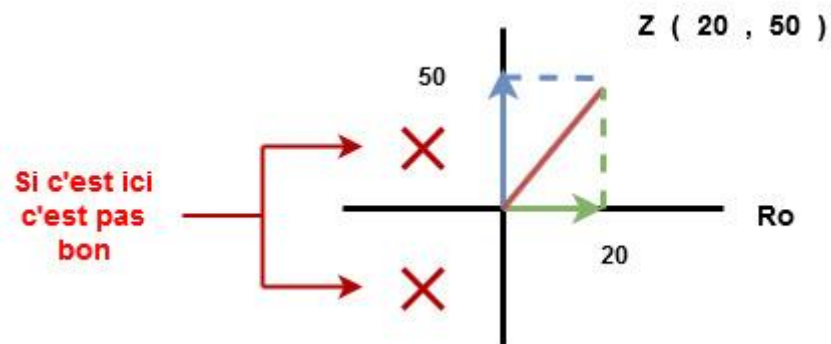
$$X_L = j \omega L = j * 2 \pi * 100 + (80 * 10^{-3}) = 50 \text{ } ^{90^\circ} \Omega$$

$$= j 50 \Omega$$

$$Z = 20 + j 50 = ?$$

$$|Z| = \sqrt{20^2 + 50^2} = 53,85$$

$$\theta = \arctg \frac{50}{20} = 68,2^\circ \quad \Rightarrow \quad \mathbf{Z} = 53,85$$



$$I = \frac{U}{Z} = \frac{10^{0^\circ}}{53,85^{68,2^\circ}} = 0,1875^{-68,2^\circ}$$

$$VR = R * I = 20^{0^\circ} * 0,1875^{-68,2^\circ} = 3,714^{-6,2^\circ} \text{ V}$$

$$\begin{aligned} VL &= XL * I = 2\pi * 100 * 30 \cdot 10^{-3} = 50^{30^\circ} * 0,1875^{-68,2^\circ} \\ &= 3,285^{21,8^\circ} \text{ V} \end{aligned}$$

Vérification : $V = VR + VC = 10^{0^\circ} ?$

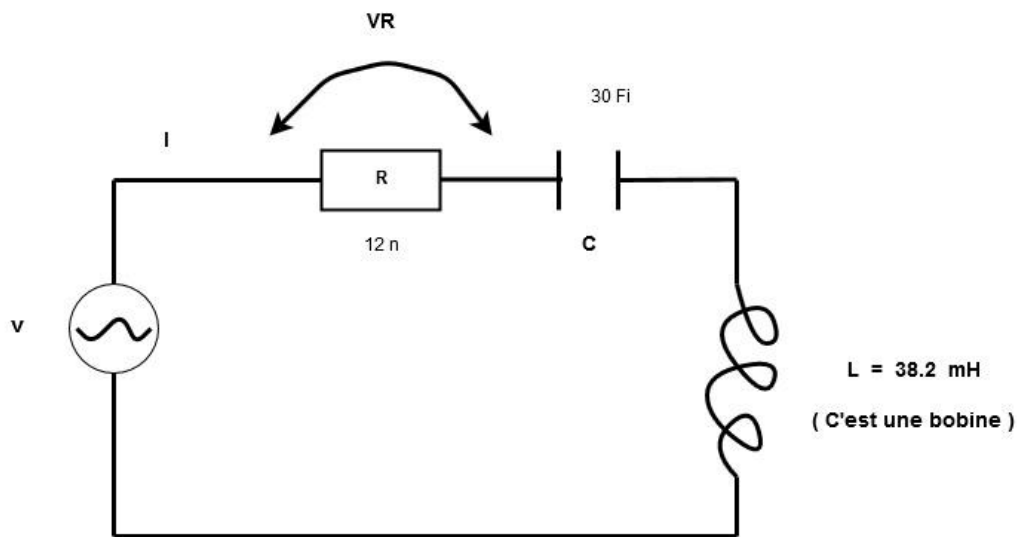
$$VR = 3,714^{-68,2} + 9,285^{21,8^\circ}$$

$$3,714 \cos (-68,2) = 1,38 \quad | \quad 9,285 \cos (21,8) = 8,62$$

$$3,714 \sin (-68,2) = -3,45 \quad | \quad 9,285 \sin (21,8) = 3,45$$

$$(1,34 + 8,62j) + (8,62 + 3,45j) = 10 \text{ V} \quad \text{OK}$$

3) Calculer : Z ; I ; V_C ; V_R ; V_L



$$Z = R + j (X_L + X_C)$$

$$X_L = jX_L = j 2 \pi * 100 * 38,2 * 10^{-3} = 24 j n = 24^{90^\circ} n$$

$$X_C = \frac{1}{jX_L} = \frac{1}{2 \pi 100 * 80 * 10^{-6}} = 20^{-90^\circ} n = -20^{90^\circ} n$$

$$Z = 12 + j(24(-20)) = 12 + 4j n$$

$$|Z| = \sqrt{12^2 + 4^2}$$

$$\rho = \arctan\left(\frac{4}{12}\right) = 18,43^\circ$$

$$\mathbf{Z} = 12,65^{18,43^\circ}$$

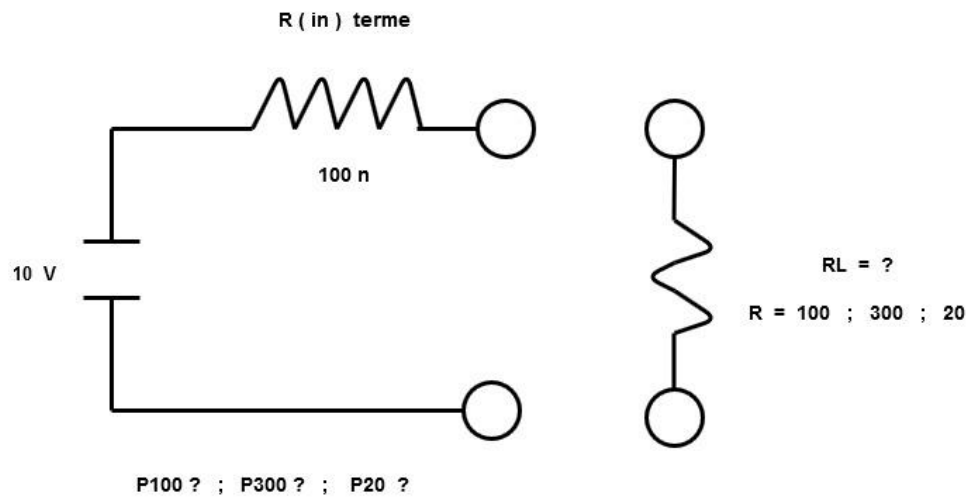
$$\mathbf{I} = \frac{U}{Z} = \frac{10^{0^\circ}}{12,65^{18,43^\circ}} = 0,79^{-18,43^\circ}$$

$$\mathbf{V_L} = X_L * I = -20^{90^\circ} * 0,79^{-18,43^\circ} = -15,8^{71,57^\circ}$$

$$\mathbf{V_C} = X_C * I = -20^{90^\circ} * 0,79^{18,43^\circ} = -15,8^{7,57^\circ}$$

$$\mathbf{V_R} = R * I = 9,49^{-18,43^\circ} V$$

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Pour RL = 100 n

$$R_{tot} = R_{in} + R_L = 100 + 100 = 200 \text{ n}$$

$$\rho_{reor} = R_{in} * I^2 = 100 * 0,05^2 = 0,25 \text{ W}$$

$$\rho_{RL} = R_L * I^2 = 100 * 0,05^2 = 0,25 \text{ W}$$

Pour RL = 300 n

$$R_{tot} = R_{in} + R_L = 300 + 100 = 400 \text{ n}$$

$$I = \frac{10}{400} = 0,025 \text{ A}$$

$$\rho_{rin} = 100 * 0,025^2 = 0,0625 \text{ W}$$

$$\rho_{resit} = 300 * 0,025^2 = 0,1875 \text{ W}$$

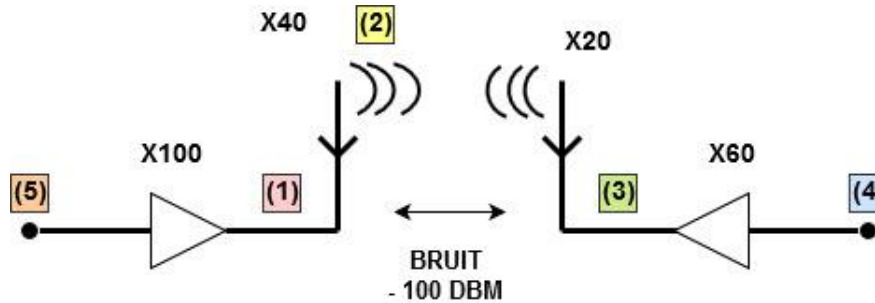
Pour $R_L = 20 \text{ n}$

$$I = \frac{10}{120} = 0,083 \text{ A}$$

$$\rho_{rin} = R_{in} * I^2 = 100 * 0,083^2 = 0,69 \text{ W}$$

$$\rho_{RL} = R_L * I^2 = 20 * 0,083^2 = 0,138 \text{ W}$$

MATH exercices en rapport avec la page inconnue (Après 25)



Calculer : (Avec en (3) on a 0,1 mW)

(1) Calculer les différentes p en dBm / dB

Emission \Rightarrow (X 100) \Rightarrow $10 \log 100 = 20 \text{ dB}$

(X 40) \Rightarrow $10 \log 40 = 16 \text{ dB}$

Source \Rightarrow (1 mW) $= 10 \log \frac{1}{1} = 0 \text{ dBm}$

Réception \Rightarrow (X 20) \Rightarrow $10 \log 20 = 13 \text{ dB}$

(X 60) \Rightarrow $10 \log 60 = 17,8 \text{ dB}$

Puissance reçue \Rightarrow (0,1 mW) \Rightarrow $10 \log \frac{0,1}{1} = - 10 \text{ dB}$

(2) Calculer la puissance d'émission (à l'antenne)

$$P_{\text{source}} * A_s * A_a = 1 * 10^{-3} * 100 * 40 = 4 \text{ W}$$

$$\begin{aligned} \text{En dBm} & \Rightarrow \text{P source (dBm)} + \text{As (dB)} + \text{Aa(dB)} = ? \\ & \quad 0 \quad + \quad 20 \quad + \quad 16 \quad = \quad 36 \text{ dBm} \end{aligned}$$

Verif $\Rightarrow 4 \text{ W} = 36 \text{ dBm} ? \Rightarrow 10 \log \frac{4000}{1} = 36 \text{ dBm}$

$$10^{\frac{36}{10}} = 10^{3,6} = 4000 \text{ mW}$$

(3) Calculer la puissance au niveau du récepteur

$$\text{En } W \Rightarrow 10^{-4} (W) * 20 * 60 = 0,12 \text{ W}$$

En dBm => - 10 (dBm) + 13 +17,8 = 20,8 dBm

Vérification :

$$(1) \Rightarrow 10 \log \frac{120}{1} \text{ (en mW)} = 20,8 \text{ dBm}$$

$$(2) \Rightarrow 10^{\frac{20,8}{10}} = 10^{\frac{2,08}{1}} = 120 \text{ mW}$$

(4) Calculer les pertes entre l'émetteur et le récepteur au niveau des antennes en dBm et en W

$$\text{En W} \quad \Rightarrow \quad \frac{1 * 10^{-4}}{4} = 25 * 10^{-6} \text{ W}$$

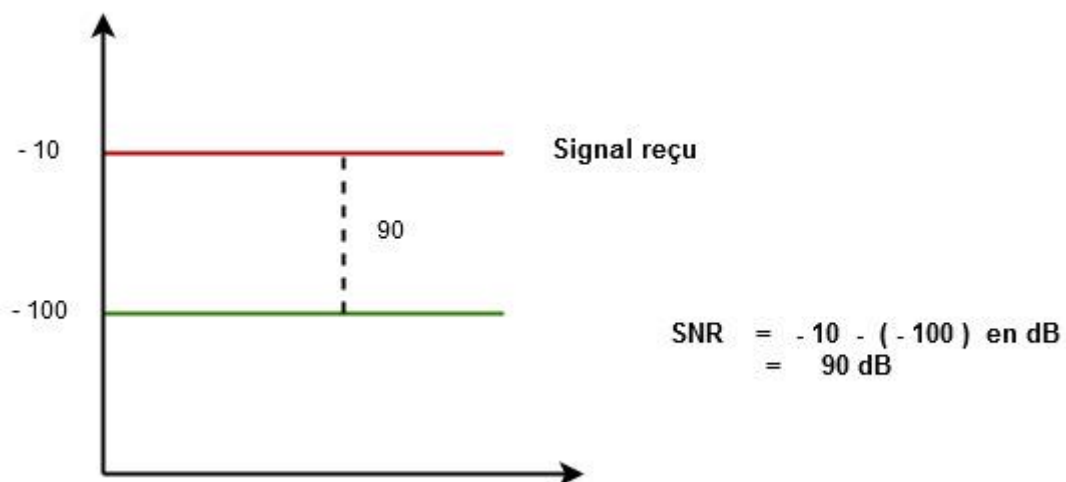
$$\text{En dB} \quad \Rightarrow \quad -10 - 36 = -46 \text{ dB}$$

Vérification :

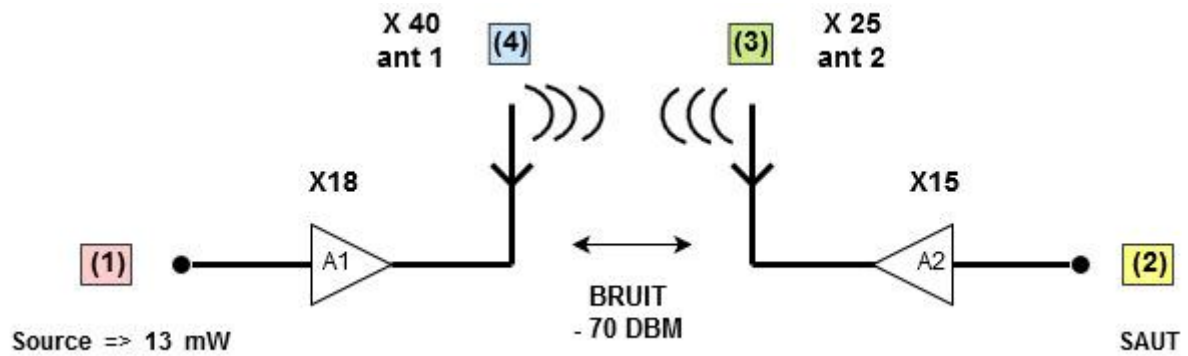
$$(1) \quad \Rightarrow \quad 10 \log 25 * 10^{-6} = 20,8 \text{ dB}$$

$$(2) \quad \Rightarrow \quad 10^{\frac{-46}{10}} = 25 * 10^{-6}$$

(5) Calculer le rapport signal sur bruit en dB et en W



Version 2 :



(A) Calculer les différents gains en dB

+ Puissance du signal en (1) et (2) en dB

$$A1 = 10 \log 18 = 12,55 \text{ dB}$$

$$A2 = 10 \log 15 = 11,76 \text{ dB}$$

$$\text{Ant 1} = 10 \log 40 = 16,02 \text{ dB}$$

$$\text{Ant 2} = 10 \log 25 = 10,79 \text{ dB}$$

$$(1) = 10 \log \frac{12}{1} = 10,79 \text{ dBm}$$

(B) Calculer la puissance d'émission (4) => en W et dBm

$$\text{En W} \quad \Rightarrow \quad (12 * 10^{-3}) * 18 * 40 = 8,64 \text{ W}$$

$$\text{En dBm} \quad \Rightarrow \quad 10,79 + 12,55 + 16,02 = 39,39 \text{ dBm}$$

Vérification :

$$\Rightarrow 10 \log (8,64 * 10^{-3}) = 39,36 \text{ dBm}$$

$$\Rightarrow 10^{\frac{39,39}{10}} = 8689 \text{ dBm}$$

(C) Calculer la puissance de réception (2 et 3) => en W et dBm

$$(4) \Rightarrow \frac{39,39 \text{ dBm}}{8,64 \text{ W}} \Rightarrow \text{Pertes} \Rightarrow (3) \Rightarrow 39,39 - 70 = -30,61 \text{ dBm}$$

$$= 10^{\frac{-30,61}{10}} = 0,87 * 10^{-3} \text{ mW} = 0,87 \text{ UW}$$

$$(3) \Rightarrow \frac{8,64}{1 * 10^7} = 0,86 \text{ UW}$$

$$\text{Perte} * -70 \text{ dB} \Rightarrow 10^{\frac{-70}{10}} = 1 * 10^{-7}$$

$$(2) \Rightarrow 0,864 * 10^{-3} \text{ mW} * 25 * 15 = 0,3265 \text{ mW}$$

$$0,864 * 10^{-3} \text{ W} * 25 * 15 = 0,3265 * 10^{-3} \text{ mW}$$

$$\text{En dBm} \Rightarrow -30,61 + 13,98 + 11,76 = -4,87 \text{ dBm}$$

Vérification :

$$\Rightarrow 10^{\frac{-4,87}{10}} = 0,3265 \text{ mW}$$

$$\Rightarrow 10 \log 0,3265 = -4,87 \text{ dBm}$$

(D) Calculer la perte entre (1) et (2)

$$-4,86 - 10,79 = -15,65 \text{ dB (Affaiblissement)}$$

$$\frac{0,3265}{12} = 2,72 * 10^{-2}$$

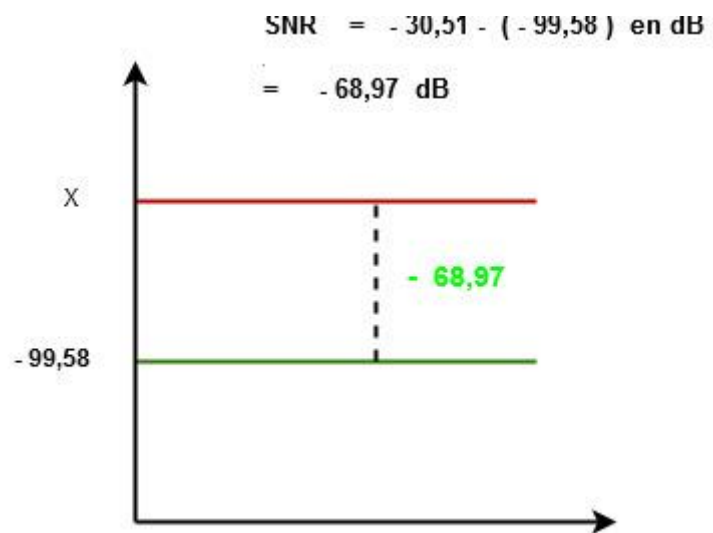
Vérification :

$$\Rightarrow 10 \log 2,72 * 10^{-2} = -15,65 \text{ dB}$$

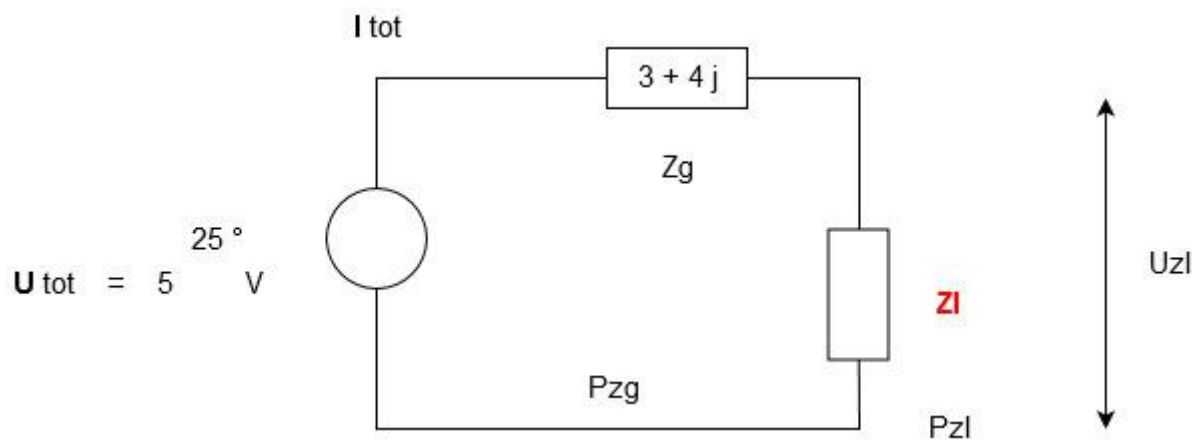
(D) SNR

$$\text{Bruit} = 1,1 * 10^{-10} \text{ mW} \Rightarrow 10 \log 1,1 * 10^{-10}$$

$$\text{Bruit} = -99,58 \text{ dBm}$$



MATH exercices en rapport avec la page 27



Exercice 1 : $Z_l = 3 + 2j \Omega$

A) Z_{tot}

$$Z_{tot} = (3 + 4j) + (3 + 2j) = 6 + 6j \Omega$$

$$\Rightarrow |Z| = \sqrt{6^2 + 6^2} = 8,48$$

$$\rho = \arctan \frac{6}{6} = 45^\circ$$

$$Z_{tot} = 8,48 \angle 45^\circ \Omega$$

B) I_{tot}

$$I_{tot} = \frac{U}{Z_{tot}} = \frac{5 \angle 25^\circ}{8,48 \angle 45^\circ} = 0,59 \angle -20^\circ A$$

C) U_{zl}

$$U_{zl} = Z_l * I_{tot} = (3 + 2j) * 0,59 \angle -20^\circ$$

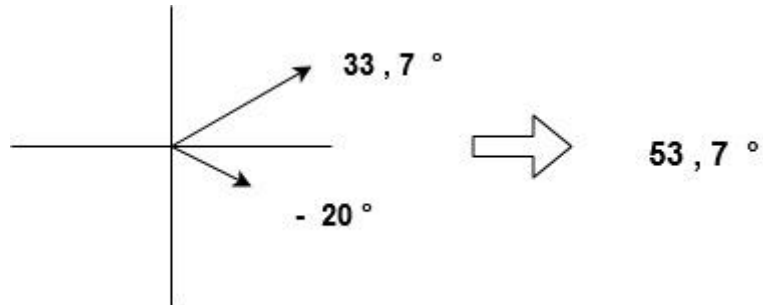
$$\Rightarrow |Z| = \sqrt{3^2 + 2^2} = 3,6$$

$$\rho = \arctan \frac{2}{3} = 33,7^\circ \Rightarrow Z_l = 3,6 \angle 33,7^\circ \Omega$$

$$U_{zl} = 3,6 \angle 33,7^\circ * 0,59 \angle -20^\circ = 2,128 \angle 13,7^\circ V$$

D) P_{zl}

$$P_{zl} = U_{zl} * I_{tot} \cos \theta$$



$$P_{zl} = 2,124 * 0,59 \cos 53,7 = 1,042 \text{ W}$$

E) P_{zg}

$$P_{zg} = U_{zg} * I_{tot} * \cos \theta$$

$$\Rightarrow U_{zg} = (3 + 4j) * 0,59^{-20} = 2,95$$

$$\Rightarrow |Z_g| = \sqrt{3^2 + 4^2} = 5$$

$$\rho = \arctan \frac{4}{3} = 53^\circ$$

$$P_{zg} = 2,95 * 0,59 * \cos [33 - (-20^\circ)] = 1,047 \text{ W}$$

F) P_{tot}

$$P_{tot} = P_{zg} + P_{zl} = 2,089 \text{ W}$$

Verification :

$$P_{tot} = U_{tot} * I_{tot} * \cos \theta$$

$$\theta = 25^\circ - (-20) = 45^\circ$$

$$P_{tot} = 2,086 \text{ W}$$

Exercice 2 : $Z_l = 4 \Omega$

A) Z_{tot}

$$Z_{tot} = (3 + 4j) + (4) = 7 + 4j \Omega$$

$$\Rightarrow |Z| = \sqrt{7^2 + 4^2} = 8,062$$

$$\rho = \arctan \frac{4}{7} = 29,75^\circ$$

$$Z_{tot} = 8,062 \angle 29,75^\circ \Omega$$

B) I_{tot}

$$I_{tot} = \frac{U}{Z_{tot}} = \frac{5 \angle 25^\circ}{8,062 \angle 29,75^\circ} = 0,62 \angle -4,75^\circ \text{ A}$$

C) U_{zl}

$$U_{zl} = Z_l * I_{tot} = (3 + 2j) * 0,59 \angle -20^\circ$$

$$\Rightarrow |Z| = \sqrt{3^2 + 2^2} = 3,6$$

$$\rho = \arctan \frac{2}{3} = 33,7^\circ \Rightarrow Z_l = 3,6 \angle 33,7^\circ \Omega$$

$$U_{zl} = 3,6 \angle 33,7^\circ * 0,59 \angle -20^\circ = 2,128 \angle 13,7^\circ \text{ V}$$

D) $P_{zl} = U_{zl} * I_{tot} * \cos \theta$

$$P_{zl} = 2,48 * 0,62 * \cos 0 = 1,5376 \text{ W}$$

E) $P_{zg} = U_{zg} * I_{tot} * \cos \theta$

$$\Rightarrow U_{zg} = (3 + 4j) * 0,62 \angle -4,75^\circ$$

$$\Rightarrow |Z_g| = \sqrt{3^2 + 4^2} = 5$$

$$\rho = 53,13^\circ$$

$$P_{zg} = 3,1 * 0,62 * \cos [48,38 - (-4,75^\circ)] = 1,153 \text{ W}$$

(Attention les rouges sont pas égaux ou presque donc pas la bonne impédance)

F) P_{tot}

$$P_{tot} = P_{zg} + P_{zl} = 2,6909 \text{ W}$$

Verification :

$$P_{tot} = U_{tot} * I_{tot} * \cos \theta$$

$$P_{tot} = 2,691 \text{ W}$$

Exercice 3 : $Z_l = 4 \Omega$

A) Z_{tot}

$$Z_{tot} = (3 + 4j) + (10j) = 3 + 14j \Omega$$

$$\Rightarrow |Z| = \sqrt{3^2 + 14^2} = 14,32$$

$$\rho = \arctan \frac{14}{3} = 78^\circ$$

$$Z_{tot} = 14,32 \angle 78^\circ \Omega$$

B) I_{tot}

$$I_{tot} = \frac{U}{Z_{tot}} = \frac{5 \angle 25^\circ}{14,32 \angle 78^\circ} = 0,35 \angle -53^\circ \text{ A}$$

C) U_{zl}

$$U_{zl} = Z_l * I_{tot} = (10j) * 0,35 \angle -53^\circ$$

$$U_{zl} = 10 \angle 90^\circ * 0,35 \angle -53^\circ = 3,5 \angle 37^\circ \text{ V}$$

$$D) \quad P_{zl} = U_{zl} * I_{tot} * \cos \theta$$

$$P_{zl} = 3,5 * 0,35 * \cos [37 - (-53)]$$

$$P_{zl} = 3,5 * 0,35 * \cos 90^\circ = 0 \text{ W}$$

$$E) \quad P_{zg} = U_{zg} * I_{tot} * \cos \theta$$

$$\Rightarrow U_{zg} = 5 \angle 53,13^\circ * 0,35 \angle -53^\circ = 1,75 \angle 0,13^\circ$$

$$P_{zg} = 1,75 * 0,35 * \cos [0,13 - (-53^\circ)] = 0,3675 \text{ W}$$

(Attention les rouges sont pas égaux ou presque donc pas la bonne impédance)

F) P_{tot}

$$P_{tot} = P_{zg} + P_{zl} = 0 + 0,3675 = 0,3675 \text{ W}$$

$$\text{Verification : } P_{tot} = 5 * 0,35 * \cos 78^\circ$$

Exercice 4 : $Z_l = 3 - 4j \, \Omega$

A) Z_{tot}

$$Z_{tot} = (3 + 4j) + (3 - 4j) = 6 \, \Omega$$

B) I_{tot}

$$I_{tot} = \frac{U}{Z_{tot}} = \frac{5^{25^\circ}}{6} = 0,83^{25^\circ} \, A$$

C) U_{zl}

$$U_{zl} = Z_l * I_{tot} = (3 - 4j) * 0,83^{25^\circ}$$

$$U_{zl} = 5^{53} * 0,83^{25} = 4,15^{-28^\circ} \, V$$

D) $P_{zl} = U_{zl} * I_{tot} * \cos \theta$

$$P_{zl} = 4,5 * 0,83 \cos [25 - (-28,13)]$$

$$P_{zl} = 3,5 * 0,35 \cos 53,13^\circ = 2,066 \, W$$

E) $P_{zg} = U_{zg} * I_{tot} * \cos \theta$

$$\Rightarrow U_{zg} = 5^{53,13} * 0,83^{25} = 4,15^{78,13}$$

$$P_{zg} = 4,15 * 0,83 * \cos [78,13 - (-25^\circ)] = 2,066 \, W$$

(Attention les rouges sont pas égaux ou presque donc pas la bonne impédance)

F) P_{tot}

$$P_{tot} = P_{zg} + P_{zl} = 4,13 \, W$$

$$\text{Verification : } P_{tot} = 5 * 0,83 * \cos 0^\circ = 4,132 \, W$$