Communication Analogique :

Chapitre 1 : Introduction

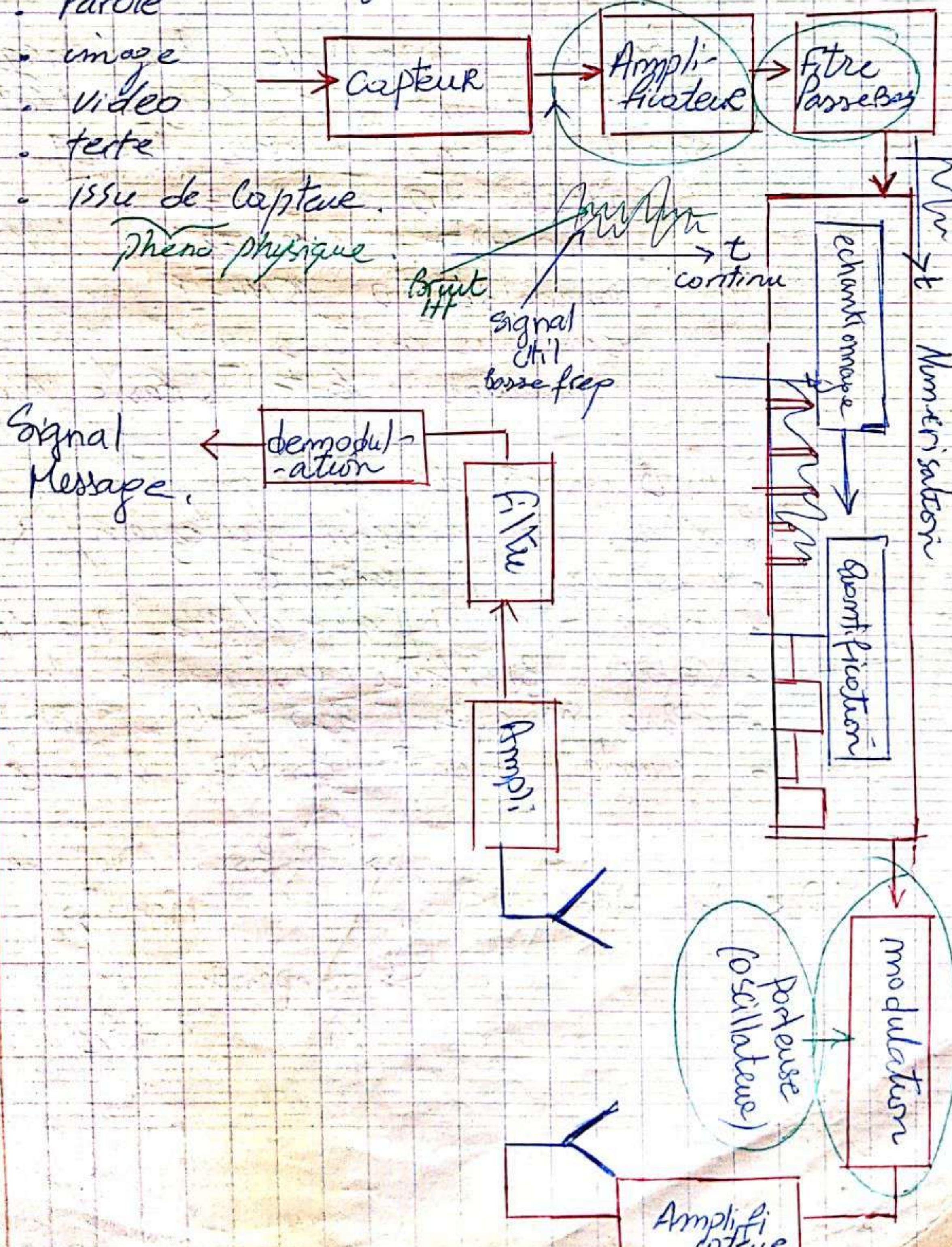
Définition :

Système de Communication

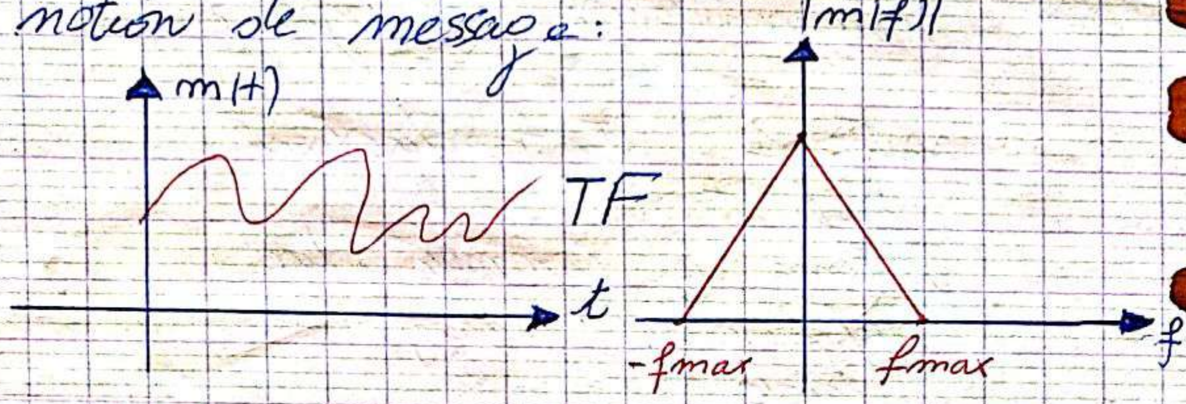
information (message)

- Parole
- image
- vidéo
- texte
- issu de Capteur.

Phéno physique.



notion de message :



Bande spectrale du msg :

- Signal audio [0 5kHz] (telephonie)
- Signal stereo [20Hz 20kHz]
  - video [0 5MHz]
  - video HD [0 10MHz]
  - image 3D [0 15MHz]

issus des capteurs [0 - quelques Hz] (variation lente) → Basse freq

Supports de transmission :

- L'air (faisceau hertzien)
- L'espace (sattellites)
- Cable coaxial [quelques MHz - 700 MHz]
- Cable Bifilaire [0, quleques 100 en kHz]
- Fibre optiques [300 GHz - 1500 GHz]
- guide d'ondes [700 MHz - 300 GHz].

Prk la Modulation → ne pas perdre le msg (Parasites ...).

→ depends de l'antène

$1/4$ $\lambda = c/f$

modulation Analogique.

AM, FM, PM (Radio)

↳ AM, DBSP (porteuse supprimée) → mixeur.

↳ BLU Bande Laterale unique → navigation

↳ BLI Bande Laterale independante → sterio

↳ BLA " " (Attenuée) → télévision

↳ QAM (Quadrature) codage Audio Visuel.

modulation Numerique:

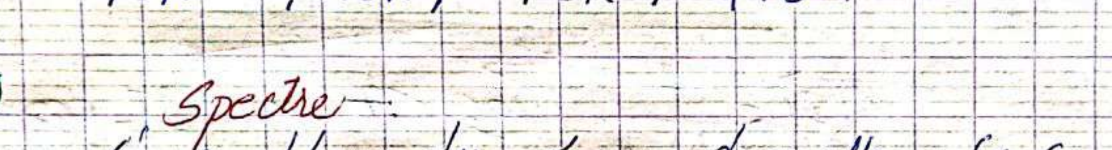
PSK, ASK, FSK, QPSK

11-2019 — Spectre:

L'ensemble des freq desquelles se compose le signal.

propriétés:

- $x(t) \xrightarrow{TF} X(f)$
- $x(t-t_0) \rightarrow X(f)e^{-j2\pi f t_0}$
- $TF[x_1(t) + x_2(t)] = TF[x_1(t)] + TF[x_2(t)]$
  $= X_1(f) + X_2(f)$.
- $TF[\delta(t)] = 1$



- $TF[A\cos 2\pi f_0 t] = \frac{A}{2}\left(\delta(f-f_0) + \delta(f+f_0)\right)$

- $TF[\frac{A}{2}\sin 2\pi f_0 t] = \frac{A}{2j}\left(\delta(f-f_0) - \delta(f+f_0)\right)$

Exemple :

$$X(f) = \int_{-\infty}^{+\infty} A \, rect\left(\frac{t}{T}\right) e^{-j2\pi f t} \, dt$$

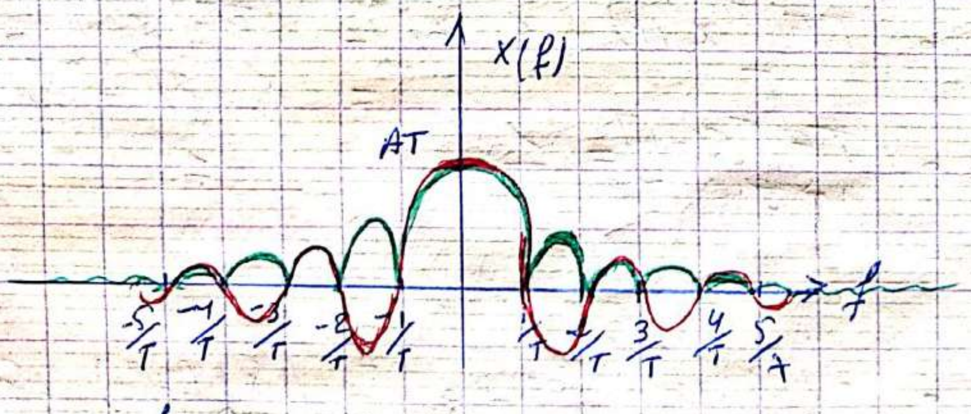
$$= \int_{-1/2}^{1/2} A e^{-j2\pi f t} \, dt$$

$$= \frac{A}{-j2\pi f} \left[e^{-j2\pi f t} \right]_{-1/2}^{1/2} = \frac{A}{-j2\pi f} \left(e^{-j\pi f t} - e^{j\pi f t} \right)$$

$$X(f) = \frac{A}{-j2\pi f} \left(\cancel{\cos \pi f t} - j\sin \pi f T \cancel{- \cos \pi f t} - \sin \pi f T \right)$$

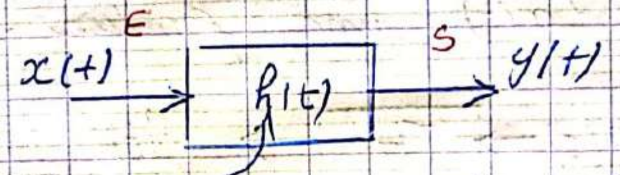
$$X(f) = \frac{A}{\cancel{-j2}\pi f} \cancel{-j2} \sin \pi f T = \frac{AT}{\pi f T} \sin \pi f t$$

$$= AT \frac{\sin \pi f T}{\pi f T} = \boxed{AT \text{ sinc } fT}$$



$$\lim_{x \to 0} \frac{\sin x}{x} = 1$$

Convolution



Réponse impulsionnelle.

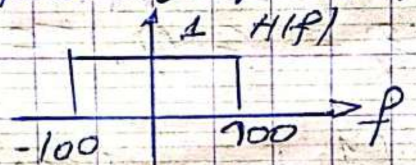
$H(f)$ = Fonction de transfert.

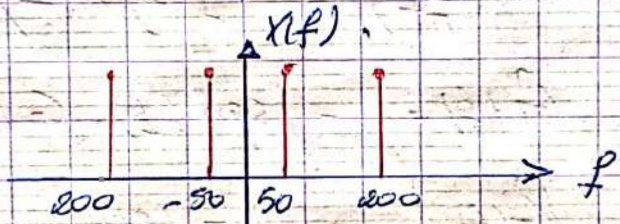
$$H(f) = S/E$$

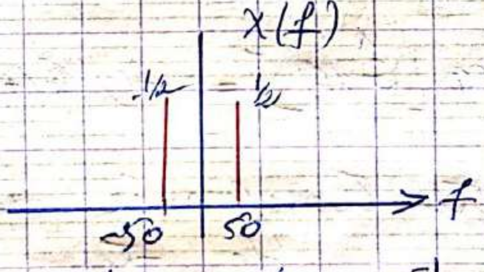
Exemple de filtrage :

$$x(t) = \cos 100\pi t + \cos 400\pi t$$

$h(t) \xrightarrow{TF}$







$$y(t) = TF^{-1}\left[y(f)\right] = TF^{-1}\left[\tfrac{1}{2}\delta(f+50) + \tfrac{1}{2}\delta(f+50)\right]$$
$$= \cos 100\pi t\,.$$

Transformée de Hilbert :

Soit $g(t)$ une fonction :

$$g(t) \rightarrow \boxed{TH} \rightarrow \hat{g}(t)$$

$$\hat{g}(t) = g(t) * \frac{1}{\pi t} = \int_{-\infty}^{+\infty} g(\tau) \frac{1}{\pi(t-\tau)} d\tau$$

propriétés : $g(t) \longrightarrow G(f)$

$\hat{g}(t) = \hat{G}(f)$

$$\hat{G}(f) = G(f) \cdot TF\left(\frac{1}{\pi f}\right)$$

$$TF\left(\frac{1}{\pi t}\right) = \underset{|\,| = 1}{-j}\ sgn(f)$$

$$\hat{G}(f) = \underbrace{-j}_{1}\,\underbrace{sgn}_{1}(f) \cdot G(f).$$

$$|\hat{G}(f)| = |G(f)|$$

$$Arg\left[\hat{G}(f)\right] = Arg(G(f)) \cdot \pi/2.$$

Cette transformée déphase le signal de $-\pi/2$

transformée de Hilbert :

TF, TL, Z $\quad t \to f$

TH $\quad t \to t$.

$$\boxed{\hat{g}(t) = TH[g(t)] = g(t) * \frac{1}{\pi t}}$$

$$\hat{g}(t) = \int_{-\infty}^{+\infty} g(\tau) \cdot \frac{1}{\pi(t-\tau)} d\tau.$$

spectre de $\hat{g}(t)$:

$$\hat{G}(f) = TF[\hat{g}(t)].$$

$$= TF\left[g(t) * \frac{1}{\pi t}\right]$$

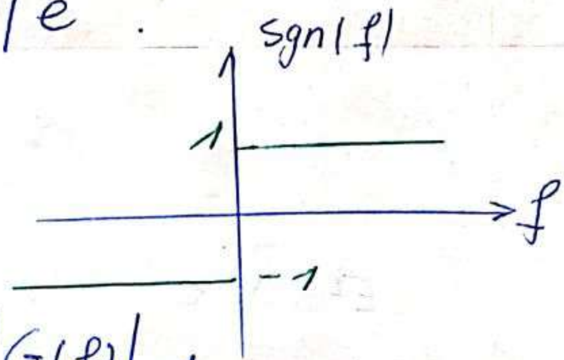
$$\hat{G}(f) = G(f) \cdot TF\left[\frac{1}{\pi t}\right].$$

OR : $\quad TF\left[\frac{1}{\pi t}\right] = -j\,\mathrm{sgn}(f)$.

$$\hat{G}(f) = -j\,\mathrm{sgn}(f) \cdot G(f).$$

$$\hat{G}(f) = |\hat{G}(f)|\, e^{j\varphi}.$$

$$|\hat{G}(f)| = ?$$



$$\Rightarrow |\hat{G}(f)| = |G(f)| \cdot 1$$

L'argument

$$\mathrm{Arg}\,(\hat{G}(f)) = -\frac{\pi}{2} + 0 + \mathrm{Arg}\,(G(f))$$

$$= \mathrm{Arg}\,G(f) - \frac{\pi}{2}$$

elle garde Le signal mais Le fait retarder de $-\frac{\pi}{2}$
(spectre Mod Amp)

Exemple : $g(t) = \cos 2\pi f_c t$.

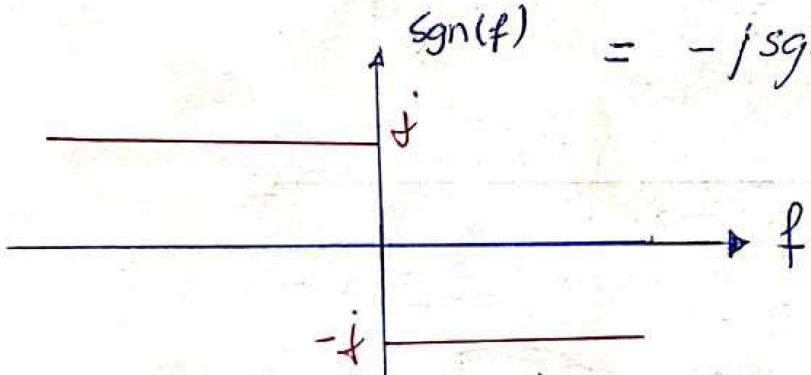
$$TH[\cos 2\pi f_c t] = \cos 2\pi f_c t * \frac{1}{\pi t}$$

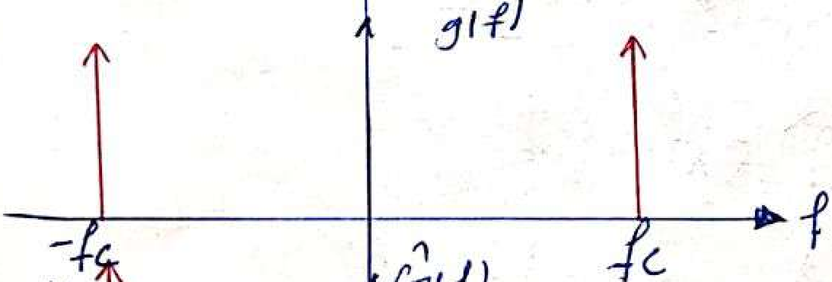
$$= \int_{-\infty}^{+\infty} (\cos 2\pi f_c \tau) \cdot \frac{1}{\pi(t-\tau)} \, d\tau.$$

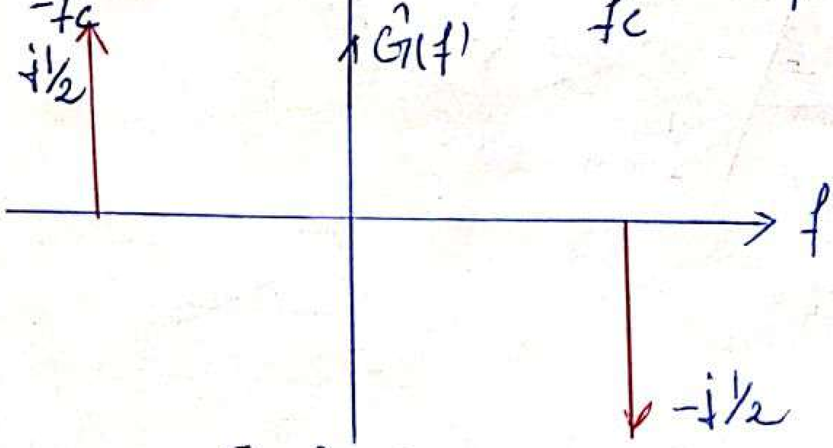
$$\hat{G}(f) \xrightarrow{TF} \hat{g}(t).$$

$$\hat{G}(f) = TF(\cos 2\pi f_c t) \cdot TF\left(\frac{1}{\pi t}\right).$$

$$= -j \, \mathrm{sgn}(f) \cdot \left(\tfrac{1}{2}\left(\delta(f-f_0) + \delta(f+f_0)\right)\right)$$







omplexe.

Et Donc :

$$\hat{G}(f) = \left(-j \tfrac{1}{2}\left(\delta(f-f_c)\right) + j\,\delta(f+f_c)\right)$$

$$= \frac{1}{j2}\left(\delta(f-f_c)\right) - \frac{1}{j2}\left(\delta(f+f_c)\right)$$

$$= \frac{1}{j2}\left(\delta(f-f_c) - \delta(f+f_c)\right)$$

$= TF\,(\sin 2\pi f_c t)$.

Forme Canonique d'un Signal :

notion d'un Signal Analitique :

$$g_+(t) = g(t) + j\,\hat{g}(t).$$

$|g_+(t)|$: pré enveloppe.

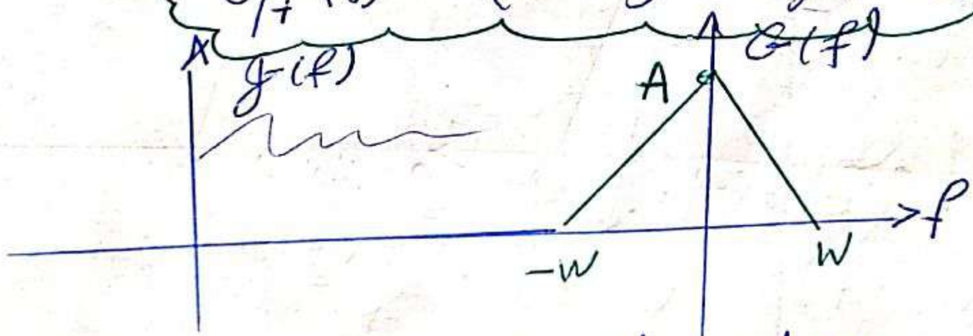
$$G_+(f) \xleftrightarrow{TF} g_+(t).$$

$$G_+(f) = G(f) + j\,\hat{G}(f).$$

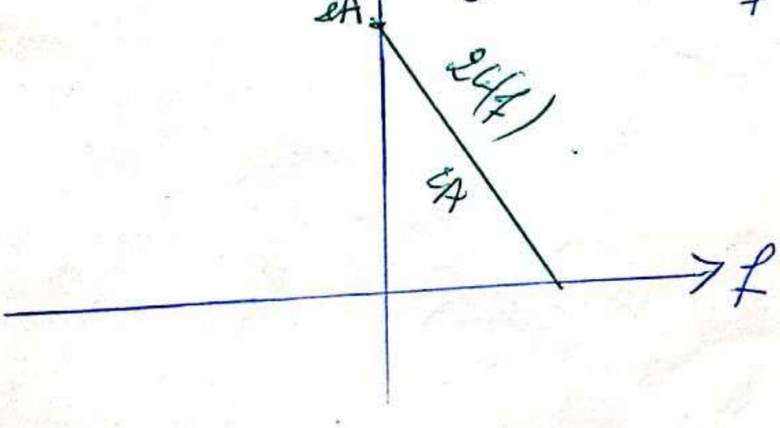
$$= G(f) + j\left(-j\,\mathrm{sgn}(f)\,G(f)\right)$$

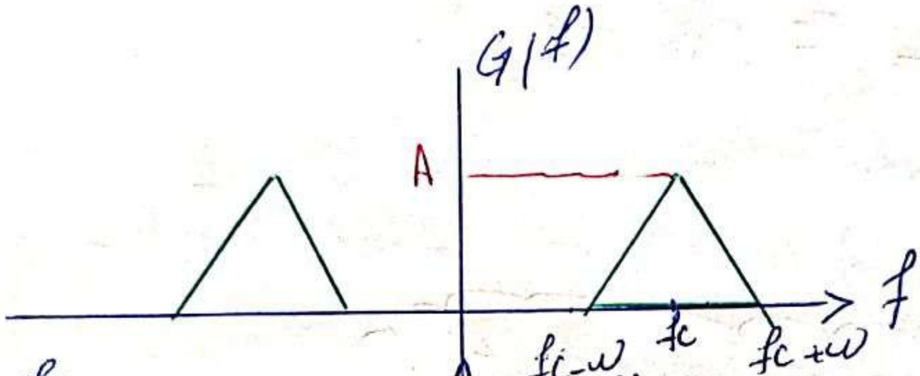
$$= G(f)\left(1 + \mathrm{sgn}(f)\right)$$

$$G_+(f) = \left(1 + \mathrm{sgn}(f)\right).G(f).$$

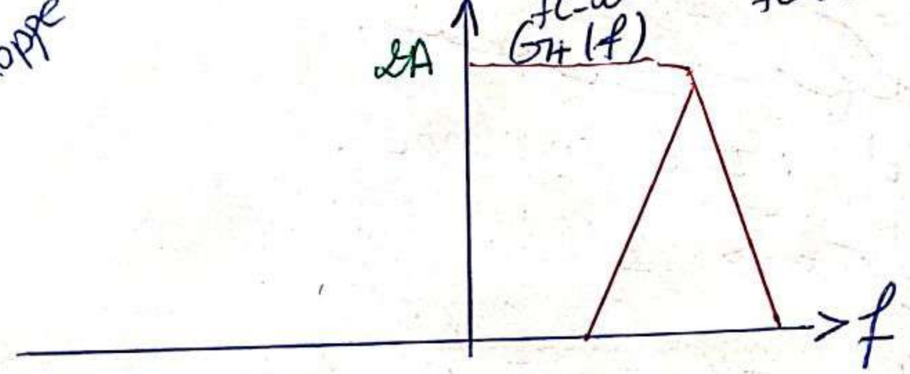


$$G_+ f = \begin{cases} 2G(f) & f > 0 \\ G(0) & f = 0 \\ 0 & f < 0 \end{cases}$$

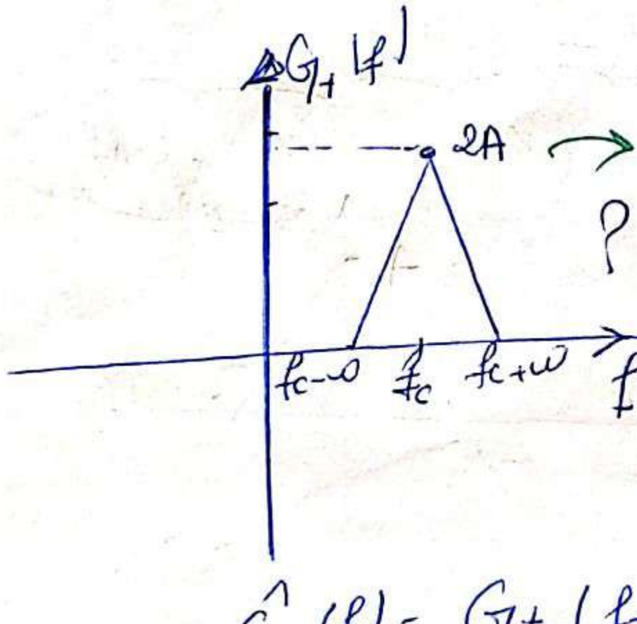




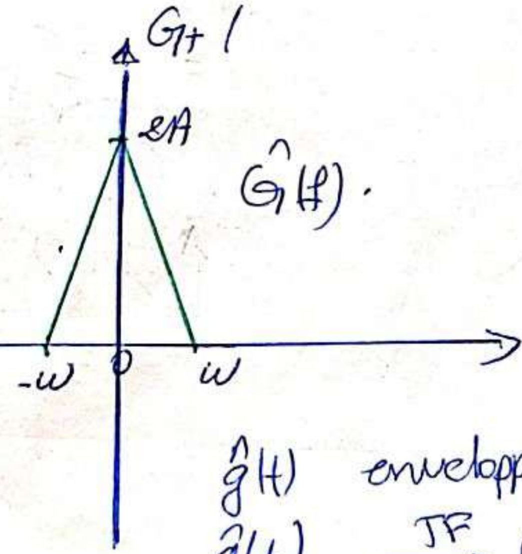
Préenveloppe



enveloppe complexe:



?



$\hat{G}(f)$.

$\hat{g}(t)$ enveloppe c

$\hat{g}(t) \xrightarrow{TF} \hat{G}(f)$

$\hat{G}(f) = G_+(f+\underbrace{f_c}_{})$

décalage gauche.

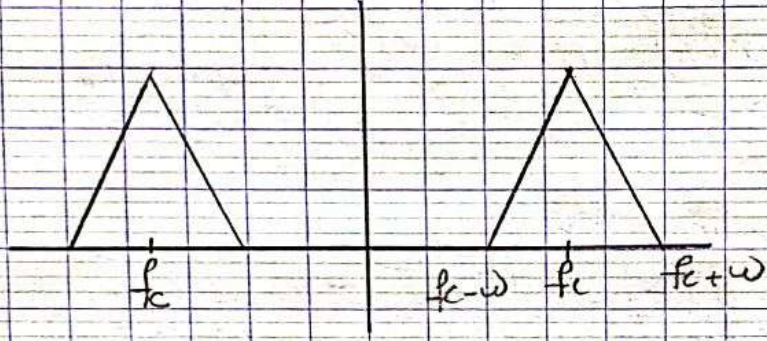
Scanné avec CamScanner

préenveloppe :

$$\hat{g}_+(t) = g(t) + j\hat{g}(t)$$

$$\hat{g}(t) = \mathcal{H}[g(t)]$$

$\hat{g}(t)$ c'est $g(t)$ déphasé de $-\frac{\pi}{2}$



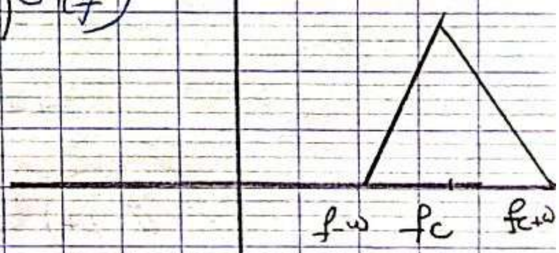
$$G_+(t) = G(f) + j\hat{G}(f)$$

or

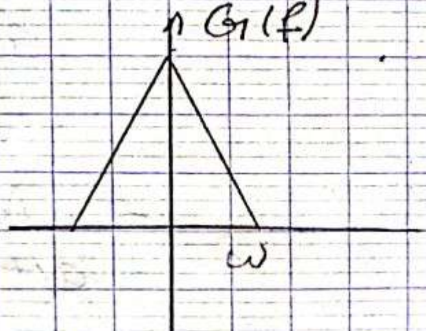
$$\hat{G}(f) = -j\,sgn(f)\,G(f)$$

$$G_+(f) = (1 + sgn(f))\,G(f)$$

$$G_+(f) = \begin{cases} 2G(f) & f > 0 \\ G(0) & f = 0 \\ 0 & f < 0 \end{cases}$$



Enveloppe Complexe



$$\tilde{G}(f) = G_+(f + f_c)$$

enveloppe complexe.

$$\hat{g}(t) = TF^{-1}[\hat{G}(f)] = TF^{-1}[G_+(f+f_c)]$$

On sais que :

$$x(t) \longrightarrow X(f)$$
$$X(f) \longrightarrow x(t)$$
$$X(f-f_0) \longrightarrow x(t)\,e^{+j2\pi f_0 t}$$
$$x(t) \longrightarrow X(f)$$
$$x(t-t_0) \longrightarrow X(f)\,e^{-j2\pi f t_0}$$

Donc ~~TF~~

$$\tilde{g}(t) = TF^{-1}[G_+(f+f_c)]$$
$$\tilde{g}(t) = g_+(t)\,e^{-j2\pi f_c t}$$

enveloppe complexe.

On a un signal

$$g_+(t) = g(t) + j\hat{g}(t)$$

$g(t)$ = signal

$$g(t) = Re[g_+(t)]$$

$$g_+(t) = \tilde{g}(t)\,e^{j2\pi f_c t}$$

$\tilde{g}(t)$ est une fct Complexe

$$\tilde{g}(t) = Re\,\tilde{g} + j\,Im\,\tilde{g}$$

Et Donc

$$g(t) = Re\left[(Re\,\tilde{g} + j\,Im\,\tilde{g})\,e^{j2\pi f_c t}\right]$$

$$= Re\left[(Re\,\tilde{g} + j\,Im\,\tilde{g})\cdot(\cos 2\pi f_c t + j\sin 2\pi f_c t)\right]$$

$$= Re\left[Re\,\tilde{g}\cos 2\pi f_c t + Re\,\tilde{g}\,j\sin 2\pi f_c t + j\,Im\,\tilde{g}\cos 2\pi f_c t - Im\,\tilde{g}\sin 2\pi f_c t\right]$$

$$g(t) = Re\left[Re\,\tilde{g}\cos 2\pi f_c t - Im\,\tilde{g}\sin 2\pi f_c t + j\left[Re\,\tilde{g}\sin 2\pi f_c t + Im\,\tilde{g}\cos 2\pi f_c t\right]\right]$$

$$g(t) = Re\,\tilde{g}\cos 2\pi f_c t - Im\,\tilde{g}\sin 2\pi f_c t$$

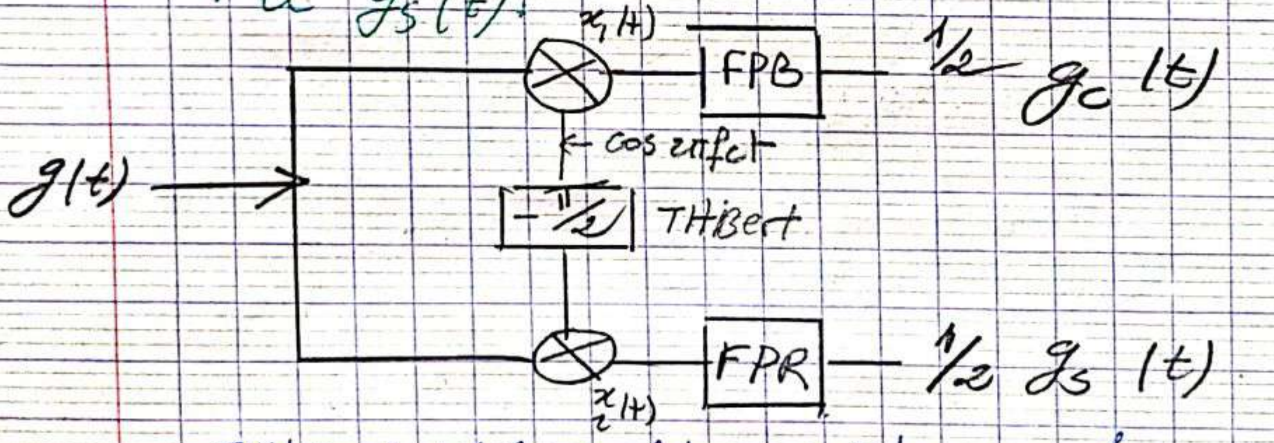
$$g(t) = g_c(t)\cos 2\pi f_c t - g_s \sin 2\pi f_c t$$

forme canonique d'un signal modulé

$g_c(t)$: Composante en phase par rapport a la porteuse

$g_s(t)$: Composante en quadrature de phase

Generation de Composante $g_c(t)$ et $g_s(t)$



$$g(t) = g_c(t)\cos 2\pi f_c t - g_s(t)\sin 2\pi f_c t.$$

$$x_1(t) = \left(g(t) \cdot \cos 2\pi f_c t\right)$$

$$= \left(g(t)\cos^2 2\pi f_c t - g_s(t)\sin 2\pi f_c t \cdot \cos 2\pi f_c t\right)$$

$$\cos x^2 = \frac{1+\cos 2x}{2} \; ; \quad = \frac{g_c(t)}{2}\left(1+\cos 4\pi f_c t\right) - \frac{g_s(t)}{2}\sin 4\pi f_c t$$

$$\frac{g_c}{2}(t) + \frac{g_c(t)}{2}\cos 4\pi f_c t - \frac{g_s}{2}\sin 4\pi f_c t$$

$$\frac{x}{2}(t) = g(t)\sin 2\pi f_c t = g_c(t)\cos 2\pi f_c t \cdot \sin 2\pi f_c t - g_s(t)\sin^2 2\pi f_c t.$$

$$= \frac{g_c(t)}{2}\sin 4\pi f_c t - \frac{g_s(t)}{2}(1 - \cos 4\pi f_c)$$

$$= \frac{-g_s(t)}{2} + \frac{g_c(t)}{2}\cdot\sin 4\pi f_c t + \frac{g_s(t)}{2}\cdot\cos 4\pi f_c t.$$

$$\begin{cases} \cos^2 x = \dfrac{1+\cos 2x}{2} \\ \sin^2 x = \dfrac{1-\cos 2x}{2} \end{cases}$$

forme canonique $g(t)$:

$$g(t) = g_c(t) \cos 2\pi f_c t - g_s(t) \sin 2\pi f_c t.$$

- $g(t)$ signal de hautes fréquences.

$g_c(t); g_s(t)$ " " Basses fréquences

forme rectangulaire :

enveloppe complexe :

$$\tilde{g}(t) = g_+(t) e^{-j 2\pi f_c t}.$$

$\tilde{g}(t) \longrightarrow g(t)$ forme rectangulaire.

$\tilde{g}(t) = g_c(t) + j g_s(t)$. On sait que : $g(t) = Re[\tilde{g}(t)]$

$\tilde{g}(t) = g_+(t) e^{-j2\pi f_c t}$ avec $g_+(t) = g(t) + j \hat{g}(t)$.

$$\tilde{g}(t) = (g(t) + j\hat{g}(t)) e^{-j2\pi f_c t}$$

or :

$$g(t) = g_c(t) \cos 2\pi f_c t - g_s(t) \sin 2\pi f_c t.$$

$$\tilde{g}(t) = (g_c(t) \cos 2\pi f_c t - g_s(t) \sin 2\pi f_c t) + j \, TH[g_c(t) \cos 2\pi f_c t - g_s(t) \sin 2\pi f_c t] e^{-j2\pi f_c t}$$

$$= [g_c(t) \cos 2\pi f_c t - g_s(t) \sin 2\pi f_c t + j \, TH[g_c(t) \cos 2\pi f_c t] - j \, TH(g_s(t) \sin 2\pi f_c t)]. e^{-j2\pi f_c t}.$$

$TH(\underbrace{m(t)}_{\text{Basse freq}} \cdot \underbrace{c(t)}_{\text{Haute freq}})]$ $TH = m(t) \cdot \hat{c}(t)$

$TH\,[\cos 2\pi f_c t] = \sin 2\pi f_c t.$

$TH\,[\sin 2\pi f_c t] = -\cos 2\pi f_c t.$

$TH\,[g_c(t)\cos 2\pi f_c t] = g_c(t).\sin 2\pi f_c t.$

$TH\,[g_s(t)\sin 2\pi f_c t] = -g_s(t).\cos 2\pi f_c t.$

$$\Rightarrow \tilde{g}(t) = \big(g_c(t)\cos 2\pi f_c t - g_s(t)\sin 2\pi f_c t + j\,g_c(t)\sin 2\pi f_c t + j\,g_s(t)\cos 2\pi f_c(t)\big).\big(\cos 2\pi f_c t - j\sin 2\pi f_c t\big)$$

$$\begin{aligned}\tilde{g}(t) = {} & g_c(t)\cos^2 2\pi f_c t - j\,g_c(t)\cos 2\pi f_c t\,.\sin 2\pi f_c t \\ & - g_s(t)\sin 2\pi f_c t\,.\cos 2\pi f_c t + j\,g_s(t)\sin^2 2\pi f_c t \\ & + j\,g_c(t)\cos 2\pi f_c t\,.\sin 2\pi f_c t + g_c(t)\sin^2 2\pi f_c t \\ & + j\,g_s(t)\cos^2 2\pi f_c t + g_s(t)\cos 2\pi f_c t\,.\sin 2\pi f_c t.\end{aligned}$$

$$\tilde{g}(t) = g_c(t) + j\,g_s(t).$$

Forme triangulaire

$$\tilde{g}(t) = \sqrt{g_c(t) + g_s(t)}\,.\,e^{j\varepsilon}.$$

$$\varepsilon = \operatorname{arctg}\frac{g_s}{g_c}$$

$$a(t) = \sqrt{g_c^2 + g_s^2}$$

$\tilde{g}(t) = a(t)\, e^{j\varphi}$

$g(t) = Re\,(g_+(t))$ or $g_+(t) = g(t) + j\hat{g}(t)$

$\tilde{g}(t)\ g_+(t)\, e^{-j2\pi f_c t}$

$g_+(t) = \tilde{g}(t) \cdot e^{+j2\pi f_c t}$.

$g(t) = Re\,[\tilde{g}(t)\, e^{j2\pi f_c t}] = Re\,[a(t)\, e^{j(2\pi f_c t + \varphi)}]$.

$g(t) = Re\,[a(t)\, e^{j(2\pi f_c t + \varphi)}]$

$= Re\,[a(t) \cos 2\pi f_c t + j\, a(t) \sin 2\pi f_c t]$

$g(t) = a(t) \cos(2\pi f_c t + \varphi)$

enveloppe d'amplitude.

Chapitre 02 : Modulation d'Amplitude Avec Porteuse.

$m(t)$ message $[-\omega, \omega]$
basse féquence.

$c(t) = A_c \cos 2\pi f_c t$

$g(t)$ = signal modulé.

$g(t) = A_c\,(1 + K m(t)) \cos 2\pi f_c t$.

K : Sensibilité du modulateur.

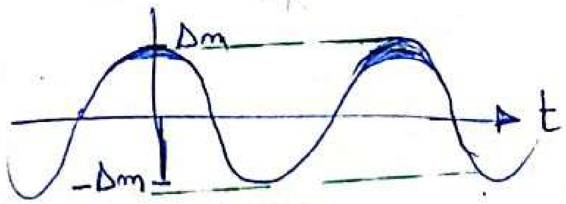
± identifier $g_c(t)$ et $g_s(t)$.

$g_c(t) = A_c\,(1 + k m(t))$.

$g_s(t) = 0$.

β) 1.7

cas où $m(t) = A_m \cos 2\pi f_m t$ taux de modulation



$$g(t) = A_c(1 + K A_m \cos 2\pi f_m t)\cos 2\pi f_c t$$

$$g(t) = A_c \cos 2\pi f_c t + A_c m \cos 2\pi f_c t \cdot \cos 2\pi f_m t$$

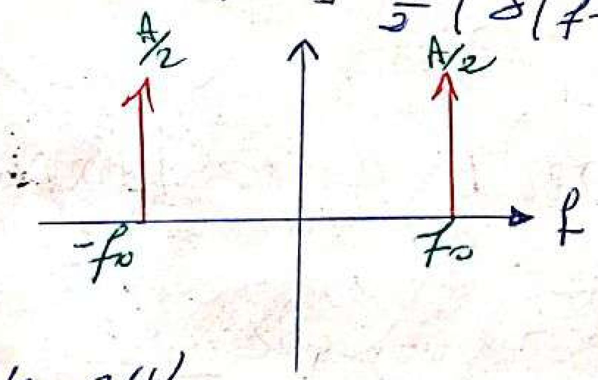
s(x).cos(y)

$$g(t) = A_c \cos 2\pi f_c t + (A_c m \cos 2\pi f_c t \cdot \cos 2\pi f_m t)$$

$$= A \cos 2\pi f_c t + \frac{A_c m}{2} \cos 2\pi (f_c - f_m)t + \frac{A_c m}{2} \cos 2\pi (f_c + f_m)t.$$

On sait que :

$$TF[A \cos(2\pi f_0 t)] = \frac{A}{2}\left(\delta(f-f_0) + \delta(f+f_0)\right)$$

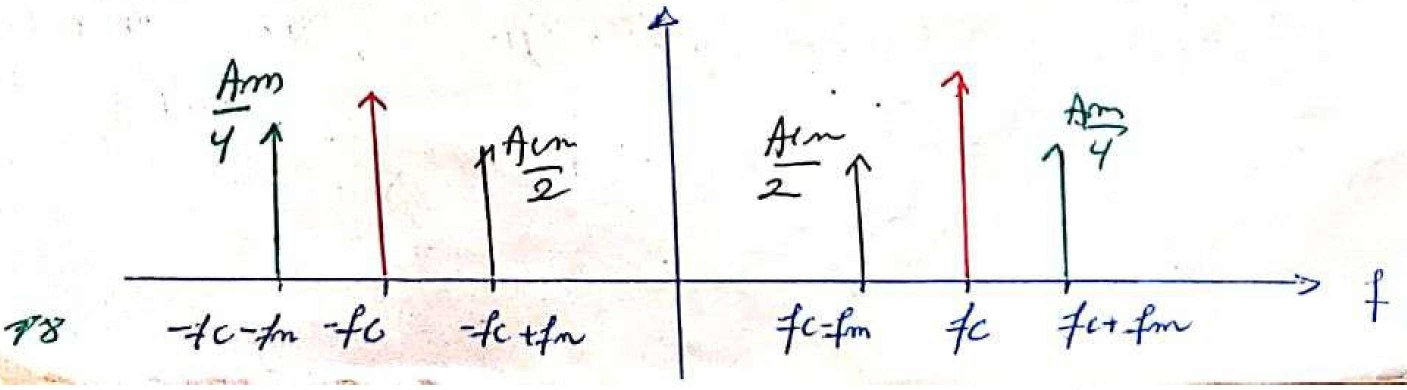


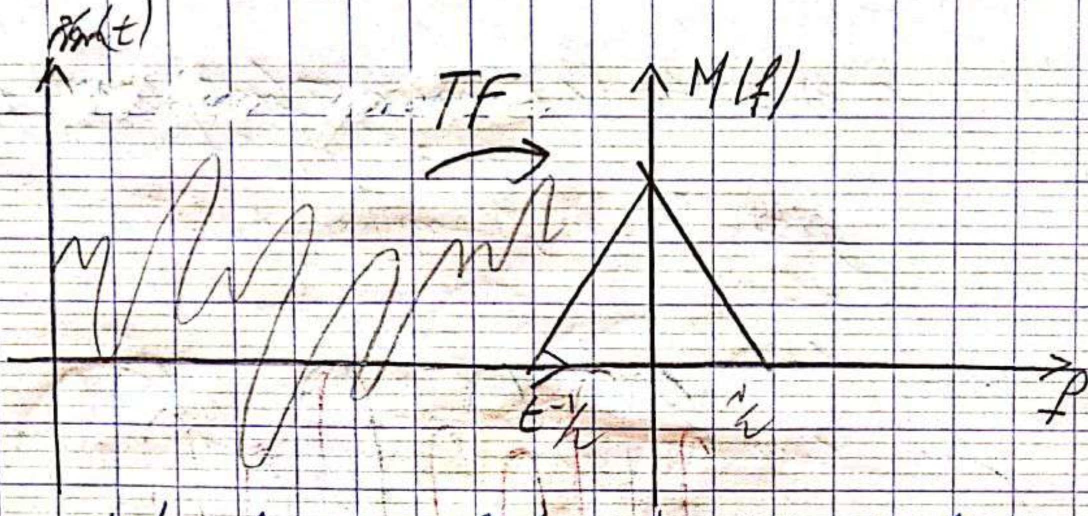
spectre de $g(t)$

$$G(f) = TF[g(t)]$$

$$= \frac{A}{2}\left(\delta(f-f_c) + \delta(f+f_c)\right) + \frac{A_c m}{4}\left(\delta(f-(f_c-f_m)) + \delta(f+(f_c-f_m))\right) +$$

$$\frac{A_c m}{4}\left(\delta(f-(f_c+f_m)) + \delta(f-(f_c+f_m))\right)$$

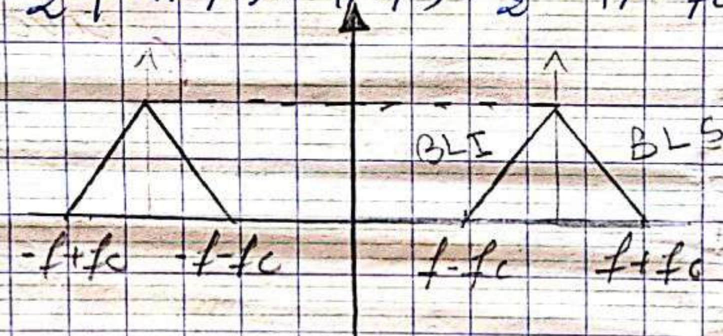




$$g(t) = A_c \cos 2\pi f_c t + k\,m(t) \cos 2\pi f_c t .$$

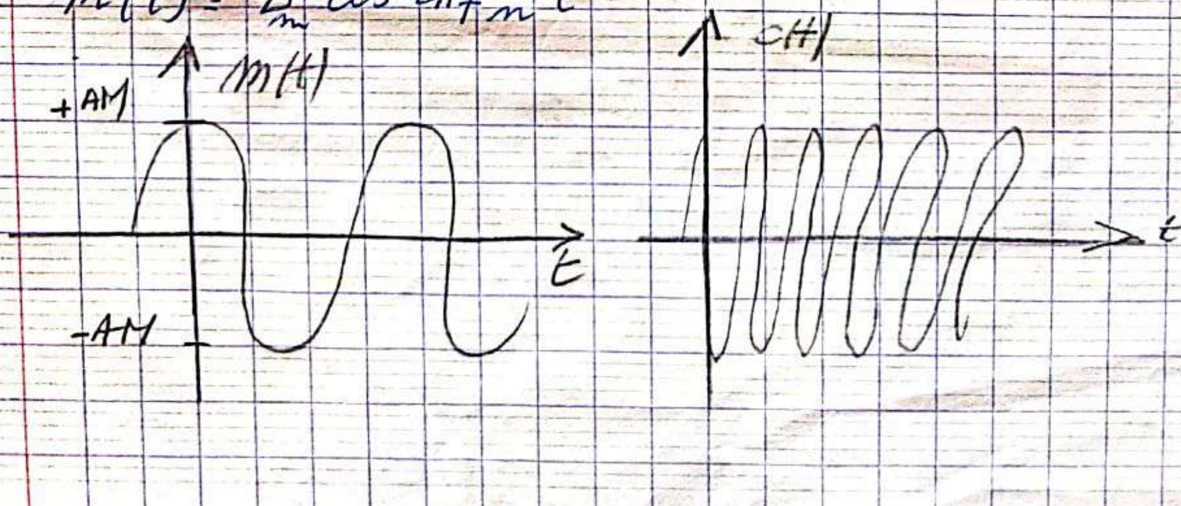
$$G(f) = \frac{A_c}{2}\left(\delta(f-f_c) + \delta(f+f_c)\right) + k\,M(f) * \frac{1}{2}\left[\delta(f-f_c) + \delta(f+f_c)\right]$$

$$= \frac{A_c}{2}\left(\delta(f-f_c) + \delta(f+f_c) + \frac{k}{2} M(f-f_c) + \frac{k}{2}(f+f_c)\right)$$



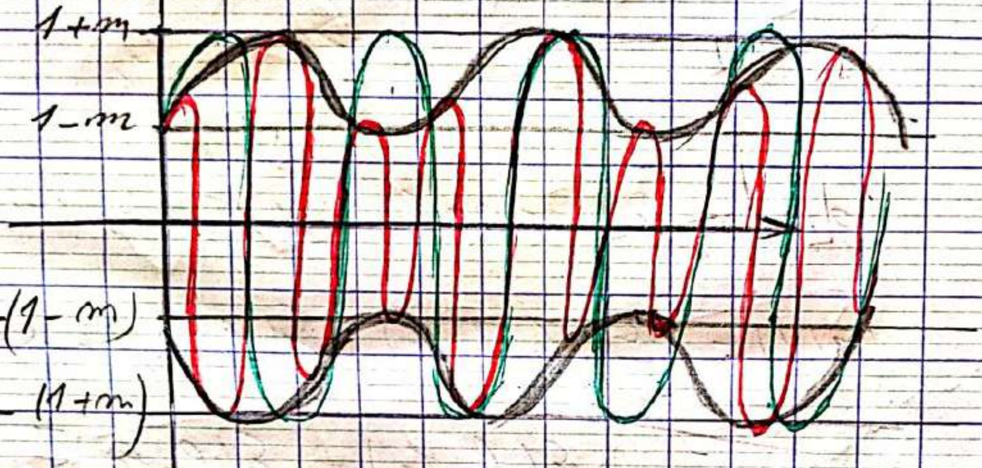
Allure d'un Signal AM.

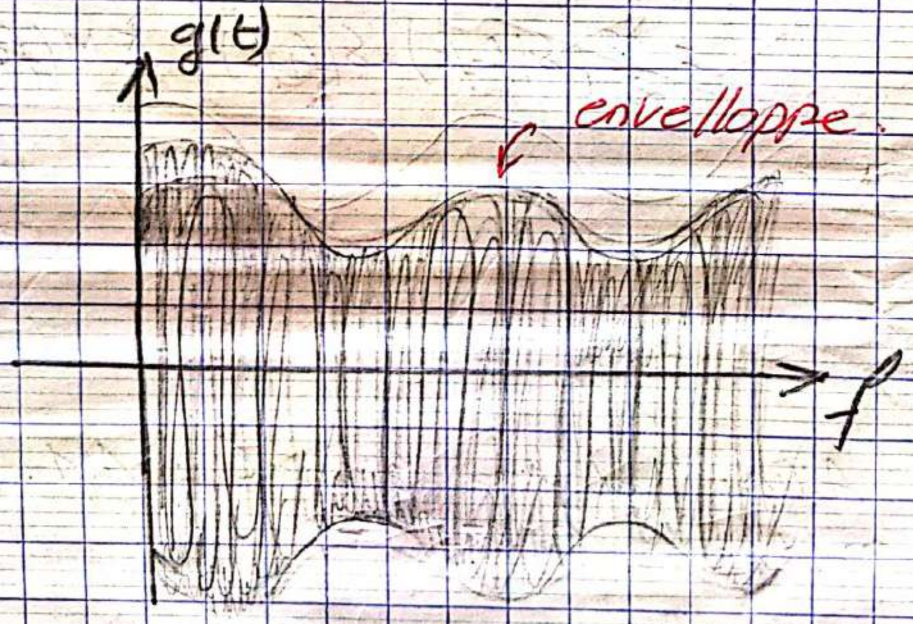
$$m(t) = A_m \cos 2\pi f_m t$$



$$g(t) = A_c\,(1 + m \underbrace{\cos 2\pi f_m t}_{[-1,1]})\,\underbrace{\cos 2\pi f_c t}_{[-1,1]}$$

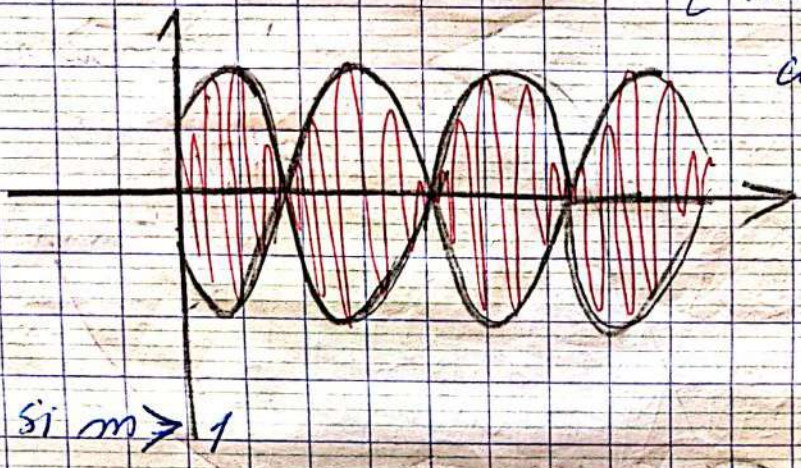
$$g(t) = [1-m,\ 1+m] \times [-1,\ 1]$$



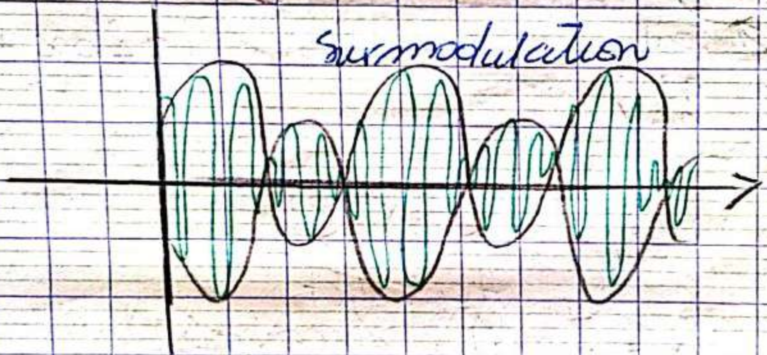


taut de modulation $[1-m, 1+m]$

si $m = 1$ $g(t) = Ac\,(1 + \underset{[-1,1]}{\cos 2\pi f_m t})\cos 2\pi f_c$



si $m > 1$



Calcule de la puissance

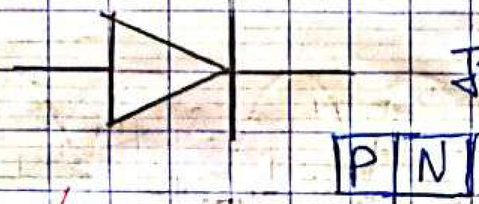
$P = \frac{V^2}{R}$ cos $\longrightarrow \frac{V_{eff}^2}{R}$, $V_{eff} = \frac{V_{max}}{\sqrt{2}}$

$(f_c - f_m) \longrightarrow \left(\frac{mAM}{2\sqrt{2}}\right)^2 / R = \frac{m^2 Am^2}{8R}$

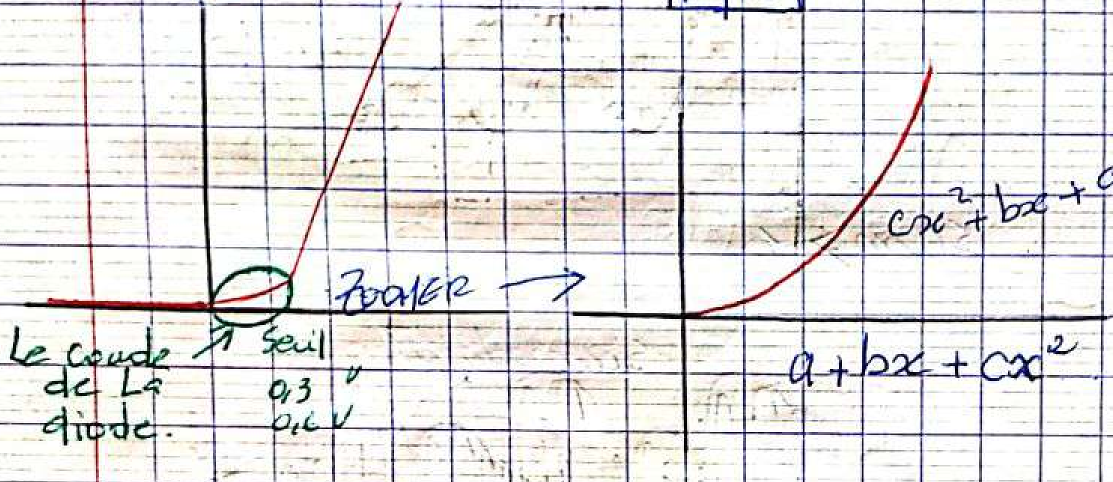
$(f_c + f_m) \longrightarrow \left(\frac{mAM}{2\sqrt{2}}\right)^2 / R = \frac{m^2 AM^2}{8R}$

$f_c \longrightarrow \left(\frac{Ac}{\sqrt{2}}\right)^2 / R = \frac{Ac^2}{2R}$

Génération d'un Signal AM :



Jonction PN → Semi Conduct SM.



$$m(t) \longrightarrow \bigotimes \xrightarrow{S_1(t)} \text{diode} \longrightarrow S(t)$$

$A_c \cos 2\pi f_c t$

$$S_1(t) = \left(m(t) + A_c \cos 2\pi f_c t\right)$$

$$S_1(t) = a + bx + cx^2$$
$$= a + b\left(m(t) + A_c \cos 2\pi f_c t\right) + c\left(m(t) + A_c \cos 2\pi f_c t\right)^2$$

$$\cos^2 x = \frac{1+\cos 2x}{2}$$

$$S_1(t) = a + b\,m(t) + b A_c \cos 2\pi f_c t + c\,m^2(t) + c A_c^2 \cos^2 2\pi f_c t + 2c\, m(t)\, A_c \cos 2\pi f_c t$$

A

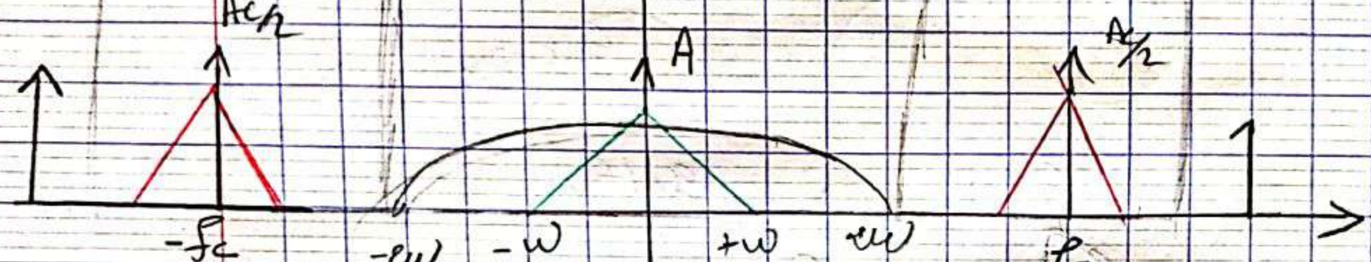
$$S_1(t) = \frac{cA_c^2}{2} + a + b\,m(t) + c\,m^2(t) + bA_c \cos 2\pi f_c t + 2A_c\, m(t) \cos 2\pi f_c t + \frac{cA_c^2}{2} \cos 4\pi f_c t$$

$$\frac{1+\cos 2x}{2} = \frac{cA_c^2 + cA_c^2 \cos 4\pi f_c t}{2}$$

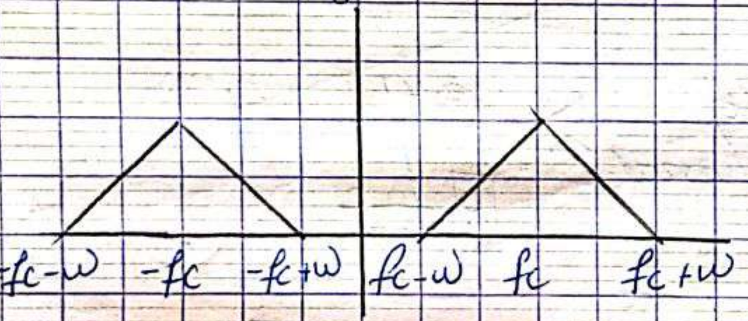
$$\frac{cA_c^2 \cdot \cos^2 2\pi f_c t}{2}$$

$$= bA_c \cos 2\pi f_c(t)\left(1 + \frac{2c}{b} m(t)\right)$$
$$= \cos 2\pi f_c(t) = \left(bA_c + 2A_c\,(m(t))\right)$$

$$S(f) = A\,\delta(f) + b\,M(f) + c\,M_2(f) + \frac{bA_c}{2}\Big[\delta(f-f_c) + \delta(f+f_c)\Big] + cA_c\Big[M(f-f_c) + M(f+f_c)\Big] + \frac{cA_c^2}{4}\Big[\delta(f-2f_c) + \delta(f+2f_c)\Big]$$



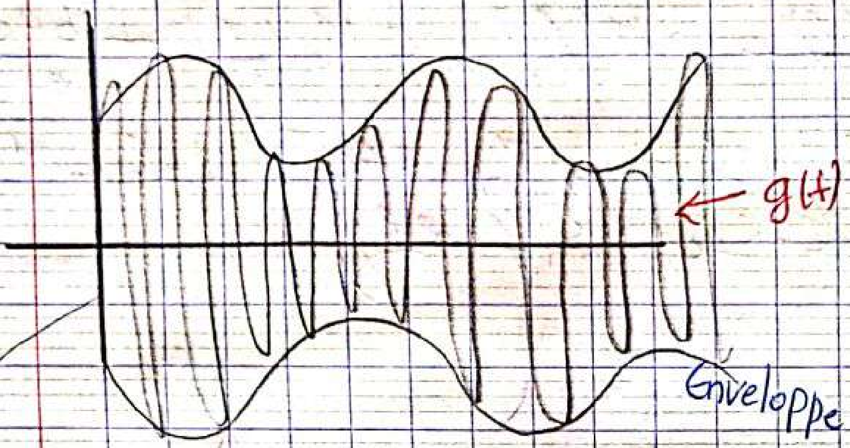
Après filtrage :

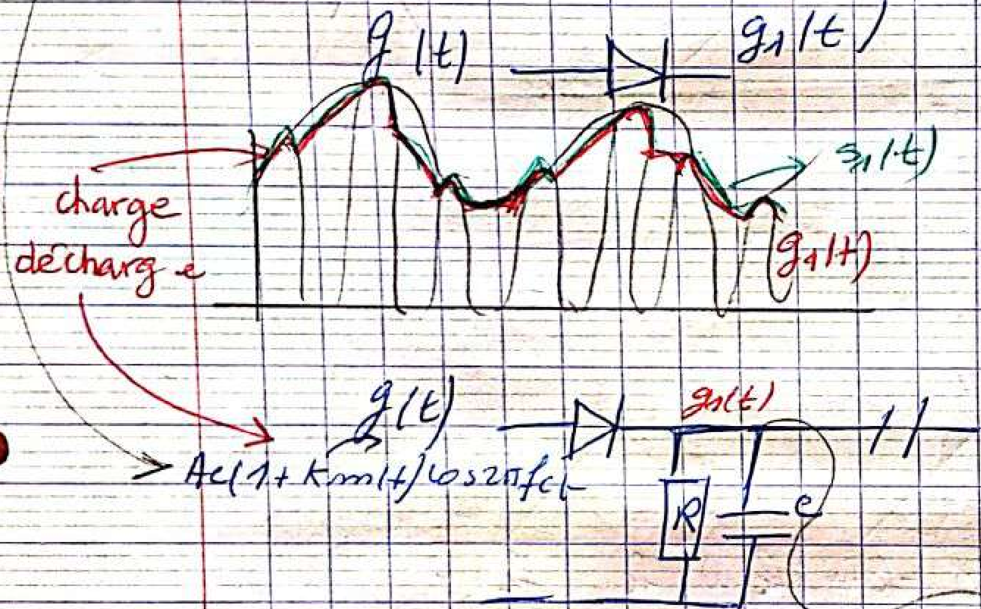


$g(t) = A_c(1 + k\,m(t))\cos 2\pi f_c t$.

Démodulation d'un signal AM.

$g(t) \rightarrow \boxed{\text{Demod}} \rightarrow m(t)$



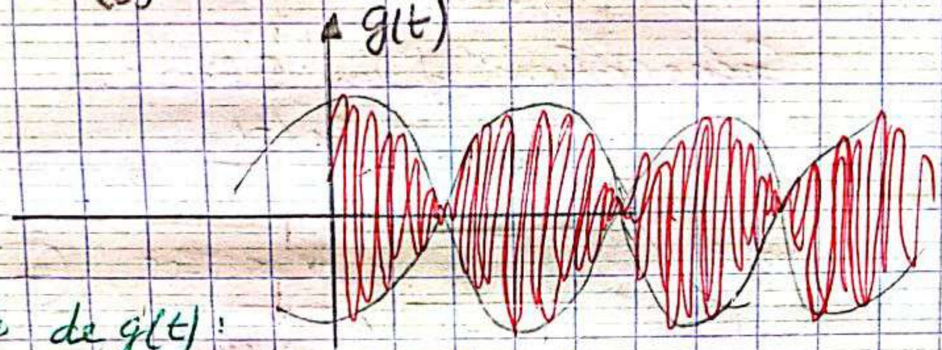


⊳ juste ⊕

C
-|| élimine
la composante
continue.

Chapitre 03 : Modulation d'amplitude Sans Porteuse.

$$Km(t) \longrightarrow \underset{Ac\cos(2\pi f_c t)}{\overset{K\ (\text{Gain de mod})}{\otimes}} \longrightarrow g(t) = Km(t).\ Ac\cos 2\pi f_c t$$



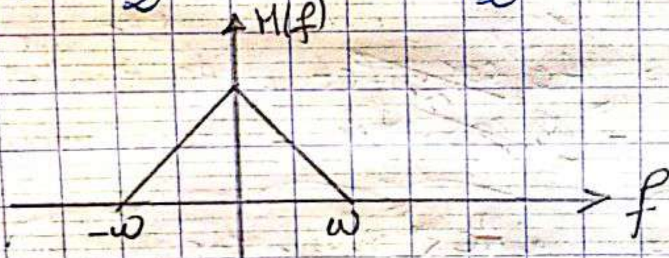
spectre de $g(t)$:

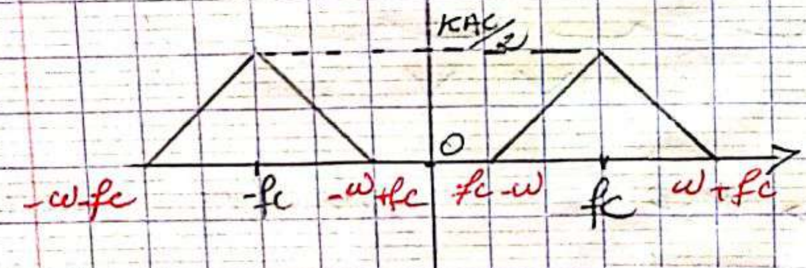
$$g(t) = K\,Ac\ m(t).\cos 2\pi f_c t$$

$$G(f) = K\,Ac\ M(f) . \frac{1}{2}\left[\delta(f-f_c) + \delta(f+f_c)\right].$$

$$G(f) = K\frac{Ac}{2}\left[M(f-f_c) + M(f+f_c)\right]$$

$$G(f) = \frac{KAc}{2}M(f-f_c) + \frac{KAc}{2}M(f+f_c).$$





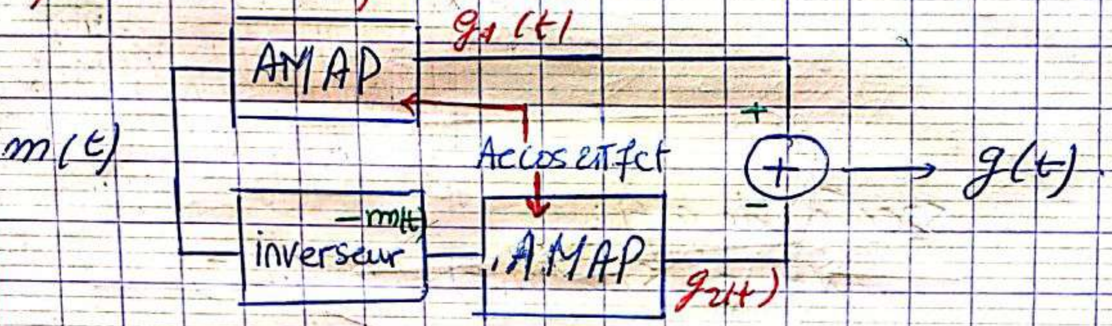
$g(t) = KA_c\, m(t) . \cos 2\pi f_c t$

forme canonique :

$$g(t) = g_c(t) \cos 2\pi f_c t - g_s(t) \sin 2\pi f_c t$$

$$\Rightarrow \begin{cases} g_c(t) = KA_c\, m(t) \\ g_s(t) = 0 \end{cases}$$

Generation d'un SAMSP.



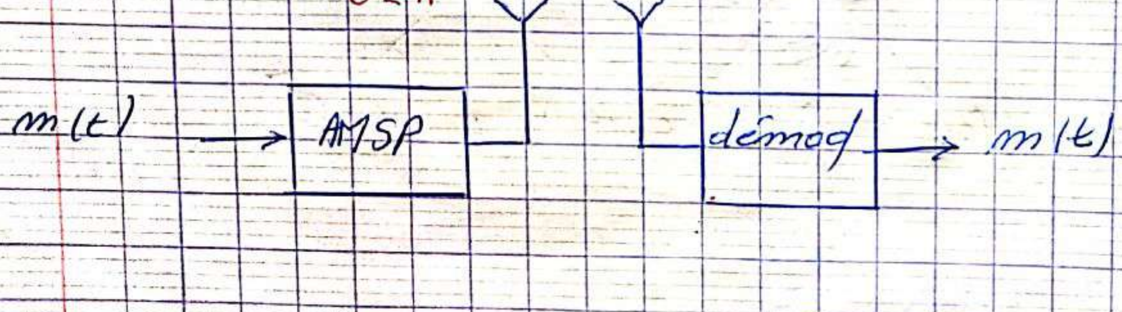
$$g(t) = g_1(t) + g_2(t)$$

$$g_1(t) = A_c(1 + km(t)) \cos 2\pi f_c t$$
$$g_2(t) = A_c(1 - km(t)) \cos 2\pi f_c t$$

$$\hookrightarrow g(t) = A_c \cancel{\cos 2\pi f_c t} + A_c K m(t) \cos 2\pi f_c (t)$$
$$- \cancel{A_c \cos 2\pi f_c} + A_c K m(t) \cos 2\pi f_c (t)$$

$$g(t) = 2A_cK\, m(t) \cos 2\pi f_c t$$

$Cte\ A'$



$\cos^2 x = \frac{1+\cos 2x}{2}$

$g(t) = A_c m(t) \cos 2\pi f_c(t) \rightarrow \otimes \rightarrow S(t)$

$\uparrow$

$A_c' \cos 2\pi f_c t$

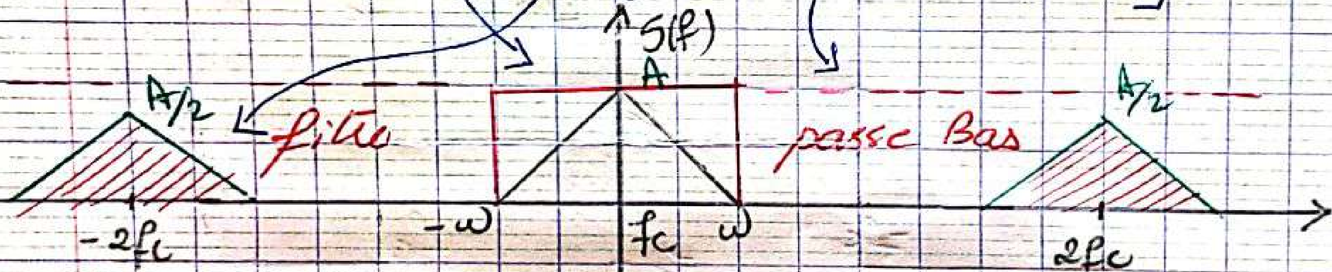
$$s(t) = A_c A_c' m(t) \cos^2 2\pi f_c t$$

$$= \frac{A_c A_c'}{2} m(t) . \left(1 + \cos 4\pi f_c t\right)$$

$$= \frac{A_c A_c'}{2} m(t) + \frac{A_c A_c'}{2} m(t) \cos 4\pi f_c t$$

$$S(t) = A m(t) + A m(t) \cos 4\pi f_c t$$

$$S(f) = A M(f) + \frac{A}{2}\left[M(f-2f_c) + M(f+2f_c)\right]$$



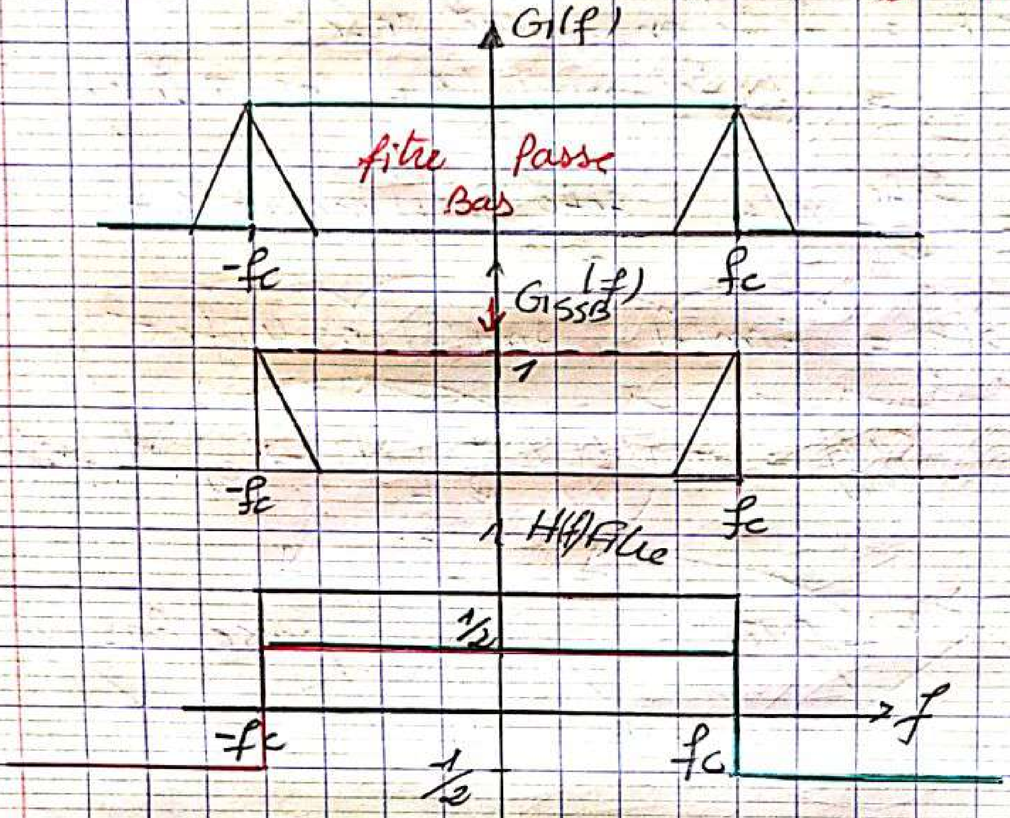
$A_c m(t) \cos 2\pi f_c t \rightarrow \otimes \rightarrow$ filtre Passe Bas $\rightarrow m(t)$

$\uparrow$

$A_c \cos 2\pi f_c t$

Chapitre 04 : Modulation à Bande latérale unique : BLU :-

SSB : Single Side Band



$$H(f) = \frac{1}{2}\,sgn(f+f_c) - \frac{1}{2}\,sgn(f-f_c)$$

$$G_{SSB}(f) = G_{AMSP}(f) \cdot H(f)$$

$$= G_{AMSP}(f) \cdot \left(\frac{1}{2}\,sgn(f+f_c) - \frac{1}{2}\,sgn(f-f_c)\right)$$

$$G_{SSB}(f) = \left[\underbrace{\frac{A_c}{2}M(f-f_c)}_{\frac{A_c}{4}M(f-f_c)} + \frac{A_c}{2}M(f+f_c)\right] \cdot \left[\frac{1}{2}sgn(f+f_c) - \frac{1}{2}sgn(f-f_c)\right]$$

$$= \frac{A_c}{4}M(f-f_c) \cdot sgn(f+f_c) - \frac{A_c}{4}M(f-f_c) \cdot sgn(f-f_c) + \frac{A_c}{4}M(f+f_c)$$
$$sgn(f+f_c) - \frac{A_c}{4}\underbrace{M(f+f_c)\,sgn(f-f_c)}_{\frac{A_c}{4}M(f+f_c)}$$

On a : $\frac{A_c}{2}M(f-f_c) \cdot \frac{1}{2}\,sgn(f+f_c) = \frac{A_c}{4}M(f-f_c)$

pour simplifier

$$\text{I} = \frac{Ac}{4}\left(M(f+fc)\,\mathrm{sgn}(f+fc)\right) = \frac{Ac}{4j}\cdot j\,(f+fc)\,\mathrm{sgn}(f+fc)$$

$$= -\frac{Ac}{4j}\left(-j\,M(f+fc)\,\mathrm{sgn}(f+fc)\right) \qquad e^{j2\pi fct}$$

$$= \frac{-Ac}{j4}\,TF\left[TH[X(t)]\right]$$

$$TF^{-1}\left[X[f+fc]\right] = x(t)\,e^{-j2\pi fct}$$

$$TF^{-1}[\text{I}] = -\frac{Ac}{j4}\,\hat{m}(t)\,e^{-j2\pi fct}$$

$$\text{II} = -\frac{Ac}{4}\frac{j}{j}\left(M(f-fc)\ \mathrm{sgn}(f-fc)\right)$$

$$X(t) \cdot \mathrm{sgn}(f)$$

$$\frac{Ac}{j4}\left(-jM(f-fc)\cdot\mathrm{sgn}(f-fc)\right)$$

$$TF^{-1}(\text{II}) = \frac{Ac}{j4}\,(\hat{m}(t))\,e^{j2\pi fct}$$

$$G_{SSB}(f) = \frac{Ac}{4}\left(M(f-fc) + M(f+fc)\right) + \text{I} + \text{II}$$

$$g_{SSB}(t) = \frac{Ac}{2}\,m(t)\cos 2\pi fct - \frac{Ac}{j4}\,\hat{m}(t)\,e^{-j2\pi fct} + \frac{Ac}{j4}\,\hat{m}(t)\,e^{j2\pi fct}$$

on developpe expo.

$$= \frac{Ac}{2}m(t)\cos 2\pi fct - \frac{Ac}{j4}\hat{m}(t)\left(\cancel{\cos 2\pi fct} - j\,\hat{m}(t)\sin 2\pi fct\right)$$

$$+ \frac{Ac}{j4}\hat{m}(t)\left(\cancel{\cos 2\pi fct} + j\,\hat{m}(t)\sin 2\pi fct\right)$$

$$= \frac{Ac}{2}m(t)\cos 2\pi fct + \frac{Ac}{2}\hat{m}(t)\sin 2\pi fct$$

à retenir

Forme canonique

$$\boxed{g_{SSB}(t) = \frac{A_C}{2} m(t) \cos 2\pi f_c t \mp \frac{A_C}{2} \hat{m}(t) \sin 2\pi f_c t}$$

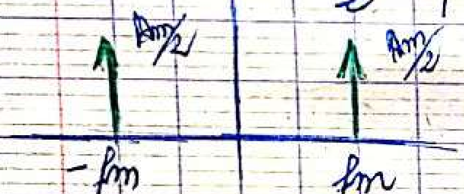
I

$$\begin{cases} g_c(t) = \dfrac{A_C}{2} m(t) \\ g_s(t) = -\dfrac{A_C}{2} \hat{m}(t) \end{cases}$$

Exemple :

$$m(t) = A_m \cos 2\pi f_m t$$

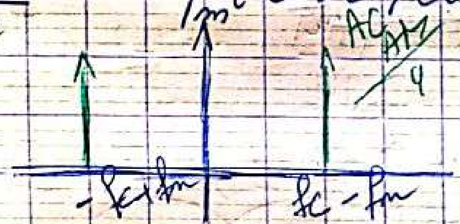
$$M(f) = \frac{A_m}{2} \left(\delta(f - f_m) + \delta(f + f_m) \right)$$



$$g(t) = \frac{A_C}{2} m(t) \cos 2\pi f_c t + \frac{A_C}{2} \hat{m}(t) \sin 2\pi f_c t$$

$$= \frac{A_M A_C}{2} \cos 2\pi f_m t \cos 2\pi f_c t + \frac{A_M A_C}{2} \sin 2\pi f_m t \sin 2\pi f_c t.$$

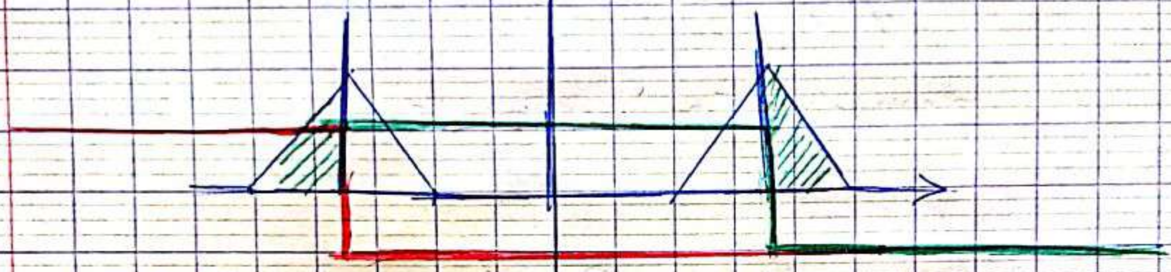
SSB Inférieure



(On envoit qu'une seule Bande du signal

Génération d'un signal SSB :

SSB- Superieur → Filtre Passe Haut.



$$H(f) = -\frac{1}{2}\text{sgn}(f+f_c) - \frac{1}{2}\text{sgn}(f-f_c)$$

*** $g_{SSB_S}(t) = \frac{A_c}{2} m(t)\cos 2\pi f_c t - \frac{A_c}{2}\hat{m}(t)\sin 2\pi f_c t$

Génération d'un Signal SSB

Demodulation AMSP :

$g(t) = A_c\, m(t) \cos 2\pi f_c t$

démodulation cohérente

$g(t) \longrightarrow \bigotimes \longrightarrow s(t) = g(t) \cdot A_c' \cos 2\pi f_c t$

$A_c' \cos 2\pi f_c t$

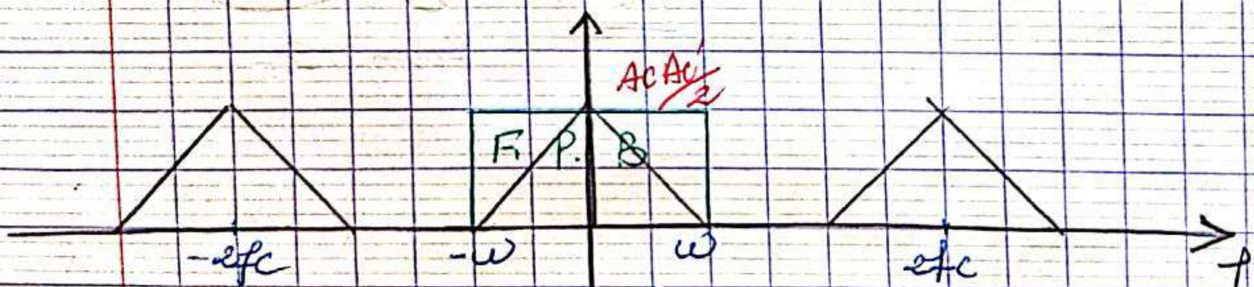
$s(t) = A_c A_c'\, m(t) \cos^2 2\pi f_c t$

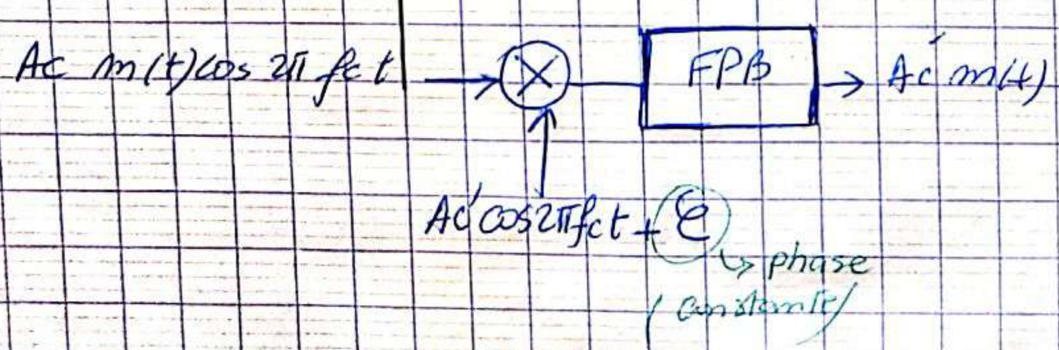
$s(t) = A_c A_c'\, m(t) \left(\frac{1 + \cos 4\pi f_c t}{2} \right)$

$s(t) = \frac{A_c A_c'}{2} m(t) + \frac{A_c A_c'}{2} m(t) \cos 4\pi f_c t$

Spectre de $s(t)$:

$S(f) = \frac{A_c A_c'}{2} M(f) + \frac{A_c A_c'}{4} \left(M(f - 2f_c) + M(f + 2f_c) \right)$





Demod SSB-I :

$$g(t) \to \otimes \to s(t) = g(t) \cdot A_c' \cos 2\pi f t$$

$A_c' \cos 2\pi f_c t$

$$s(t) = \frac{A_c A_c'}{2} m(t) \cos^2 2\pi f_c t + \frac{A_c A_c'}{2} \hat{m}(t)$$

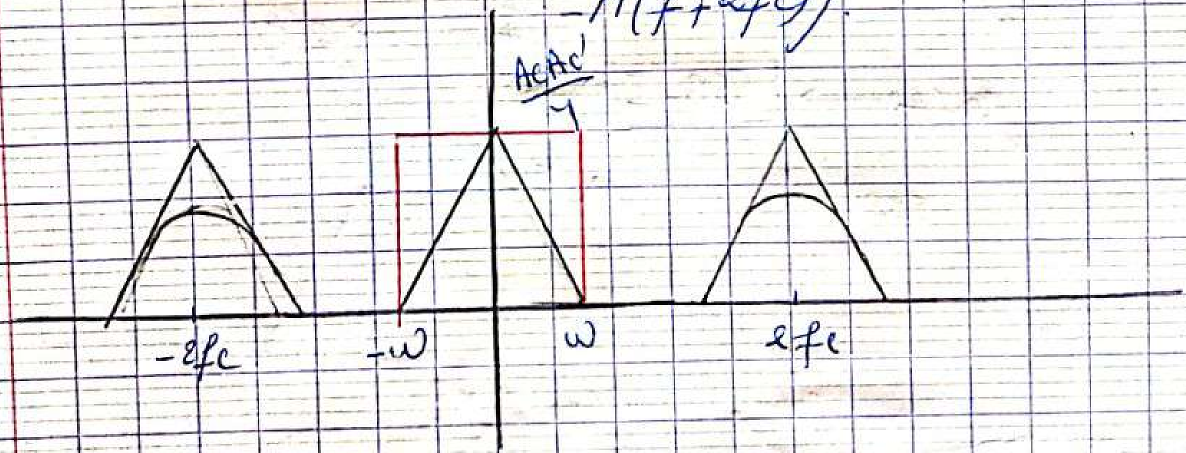
$\cos 2\pi f_c t \cdot \cos 2\pi f t$

$$s(t) = \frac{A_c A_c'}{4} m(t) (1 + \cos 4\pi f t) + \frac{A_c A_c'}{4} \hat{m}(t) \sin 4\pi f$$

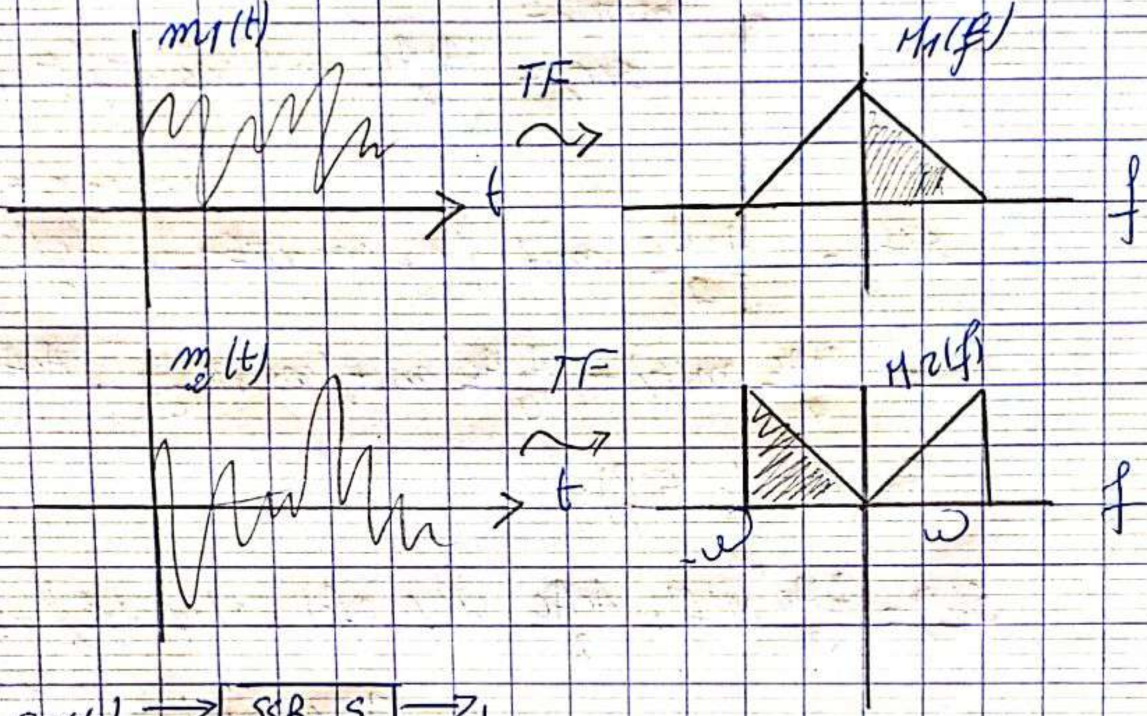
$$= \frac{A_c A_c'}{4} m(t) + \frac{A_c A_c'}{4} m(t) \cos 4\pi f_c t + \frac{A_c A_c'}{4} \hat{m}(t) \sin 4\pi f t$$

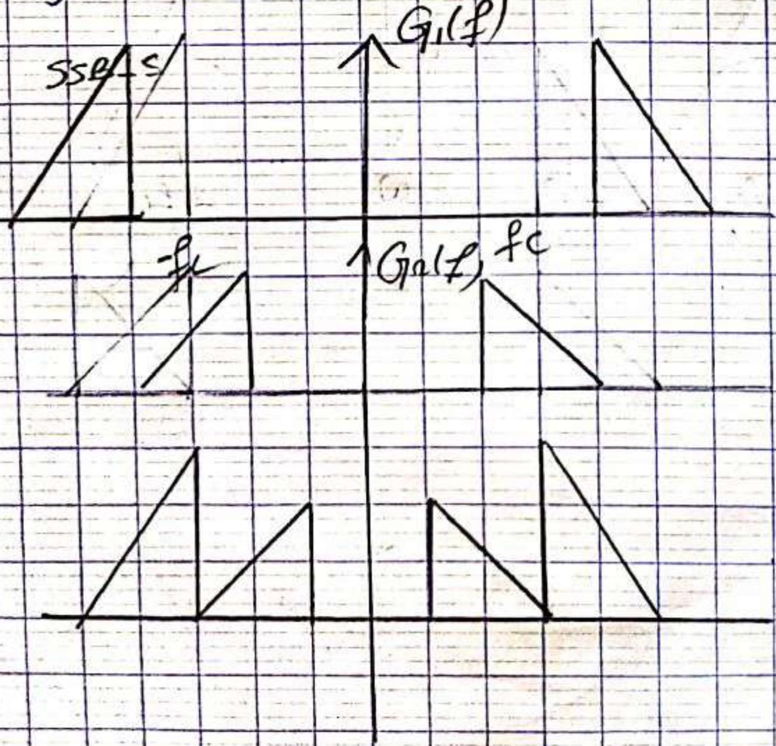
Spectre de $S(f)$:

$$S(f) = \frac{A_c A_c'}{2} M(f) + \frac{A_c A_c'}{8} \left[M(f - 2f_c) + M(f + 2f_c) \right] + \frac{A_c A_c'}{j8} \left[\hat{M}(f - 2f_c) - \hat{M}(f + 2f_c) \right]$$



Modulation bande latérale Indépendantes
BLI

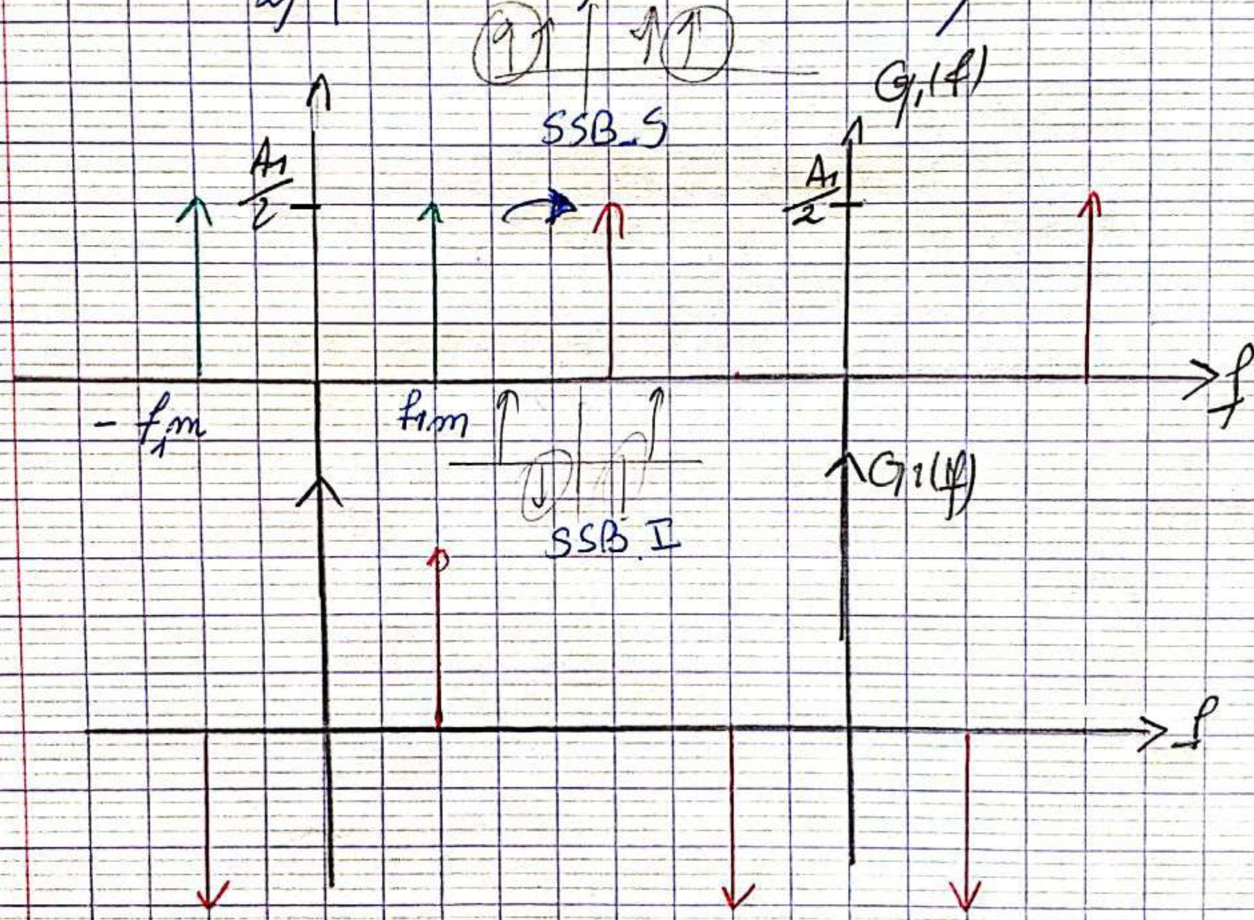




$$\begin{cases} m_1(t) = A_1 \cos 2\pi f_{m_1} t \rightarrow SSB\_S \\ m_2(t) = A_2 \sin 2\pi f_{m_2} t \rightarrow SSB\_I . \end{cases}$$

$$M_1(f) = \frac{1}{2}\left(\delta(f - f_{1m}) + \delta(f + f_{m_1})\right)$$

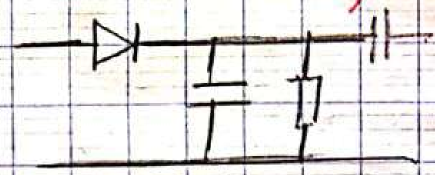
$$M_2(f) = \frac{1}{2j}\left(\delta(f - f_{2m}) - \delta(f + f_{m_2})\right)$$

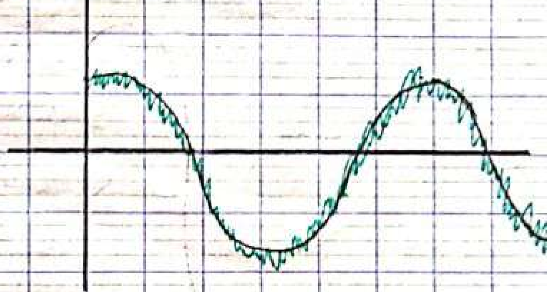


14-01-2019

Demodulation

①- detection d'enveloppe





② démodulation Synchrone

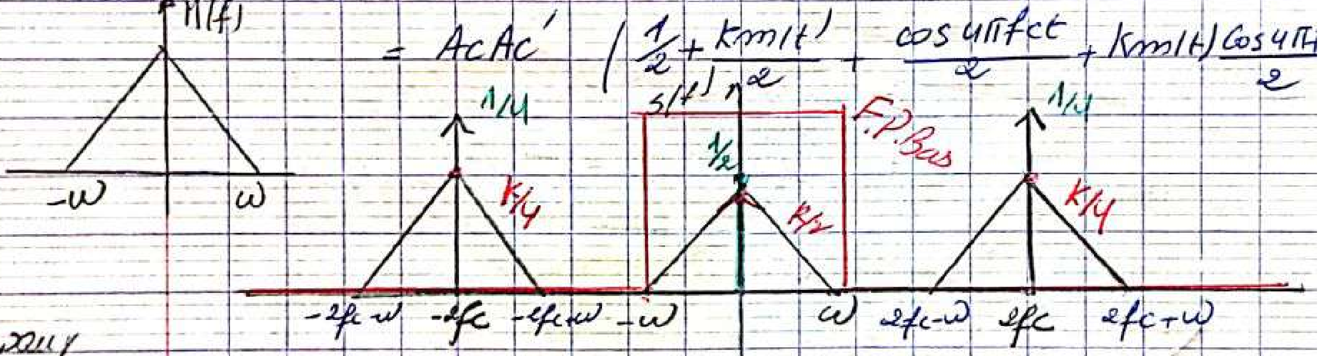
$$g(t) \longrightarrow \otimes \longrightarrow s(t) = A_cA_c'(1+km(t))\cos^2 2\pi f_c t .$$

$g(t) = A_c(1+Km(t))\cos 2\pi f_c t$

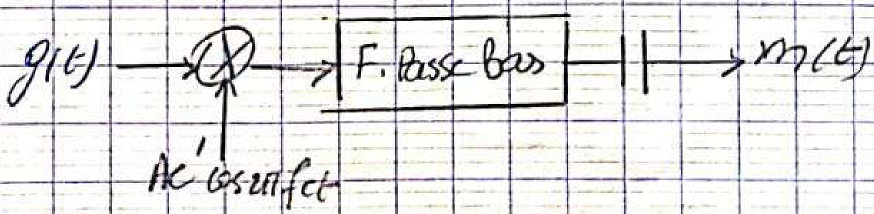
$A_c'\cos 2\pi f_c t$

$$S(t) = A_cA_c'(1+km(t))\left(\frac{1+\cos 4\pi f_c t}{2}\right)$$

$$= A_cA_c'\left(\frac{1}{2}+\frac{km(t)}{2}+\frac{\cos 4\pi f_c t}{2}+km(t)\frac{\cos 4\pi f_c t}{2}\right)$$

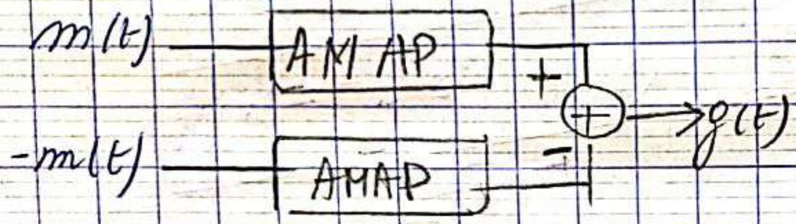


pour éliminer la composante continu on doit rajouter un ⊣⊢



modulation AM sans porteuse

$g(t) = K A_c\, m(t) \cos 2\pi f_c t.$



$g(t) = A_c(1+km(t))\cos 2\pi f_c t - A_c(1-km(t))\cos 2\pi f_c t$

$= A_c\cos 2\pi f_c t + A_c k\, m(t)\cos 2\pi f_c t + A_c \cos 2\pi f_c t +$

$A_c k\, m(t) \cos 2\pi f_c t$

$g(t) = 2kA_c\, m(t) \cos 2\pi f_c t.$

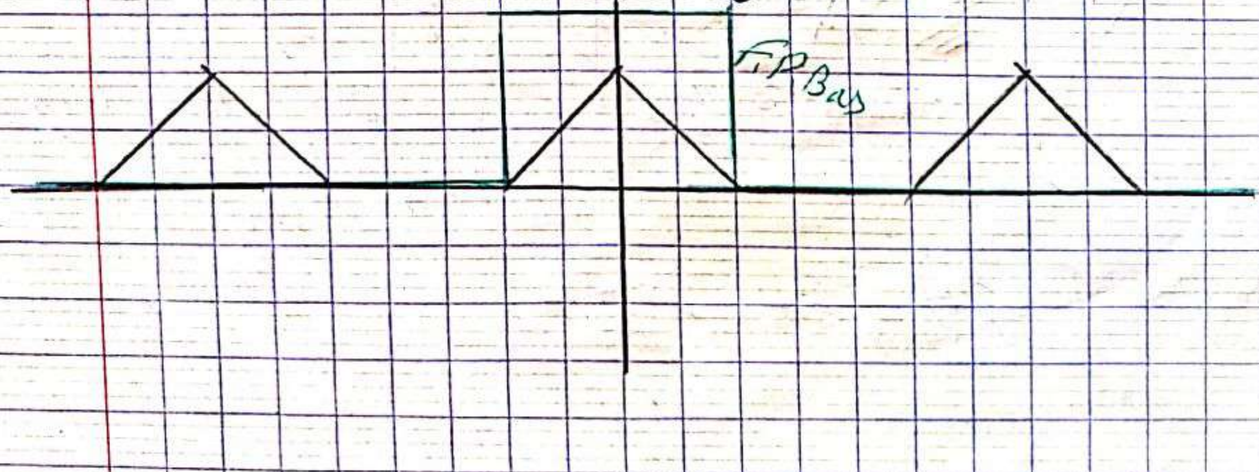
démodulation cohérente synchrone:

$g(t) \rightarrow \otimes \rightarrow$

$A_c' \cos 2\pi f_c t$

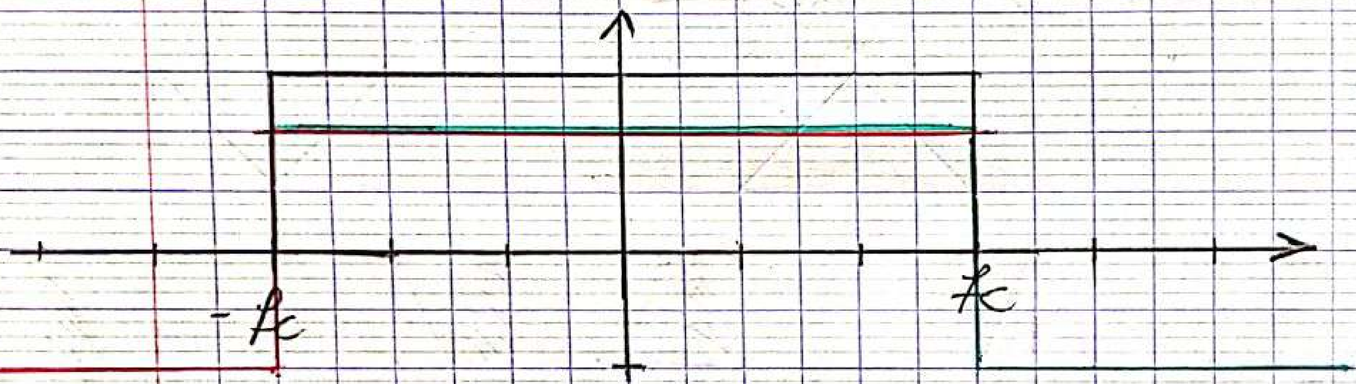
$s(t) = A_c A_c' m(t) \cos^2 2\pi f_c t = \frac{A_c A_c'}{2} m(t) (1+km(t)) \cos 2\pi f_c t)$

$= \frac{A_c A_c'}{2} m(t) + \frac{A_c A_c'}{2} m(t) \cos 4\pi f_c t.$



SSB - Bande laterale unique:

$$G_{SSB}(f) = H(f)\, S(f).$$



$$H(f) = \frac{1}{2}\,sgn(f+fc) - \frac{1}{2}\,sgn(f-fc).$$

$$G(f) = \left(\frac{Ac}{2}\left(M(f-fc) + M(f+fc)\right)\right)\left(\frac{1}{2}\left(sgn(f+fc) - sgn(f-fc)\right)\right)$$

Hilbert $g(t) = \frac{Ac}{2}\, m(t) \cos 2\pi fct + \frac{Ac}{2}\, \hat{m}(t) \sin 2\pi fct$

Démodulation :

Bande laterale indépendante : BLI

2 msg differents $m_1(t)$ et $m_2(t)$

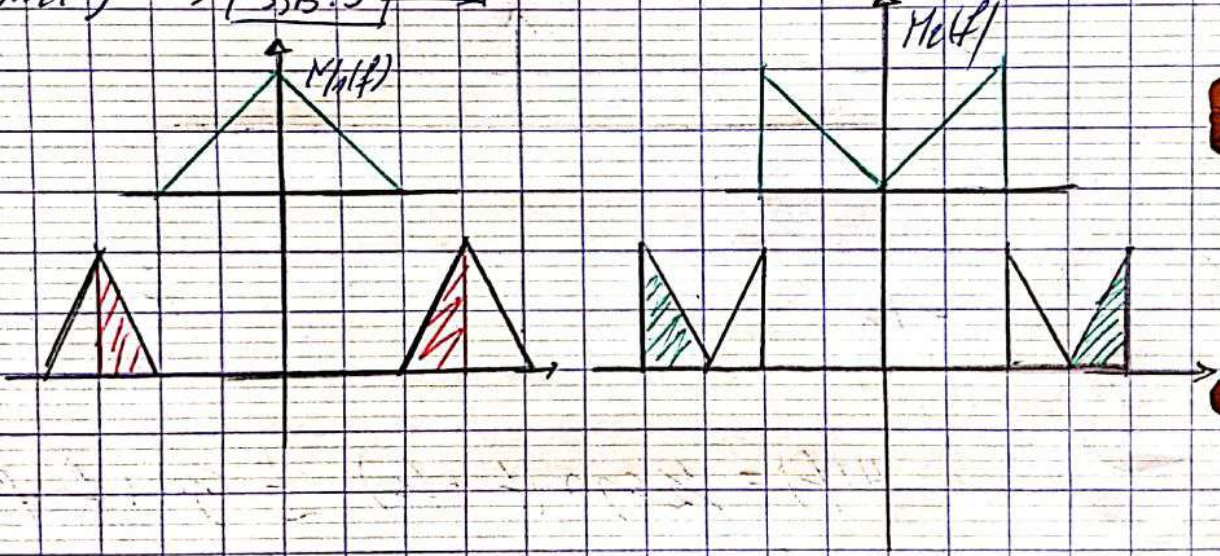
$m_1(t) \rightarrow BLI$

$m_2(t) \rightarrow BLS$

$m_1(t) \longrightarrow \boxed{SSB.I} \xrightarrow{+} \oplus$

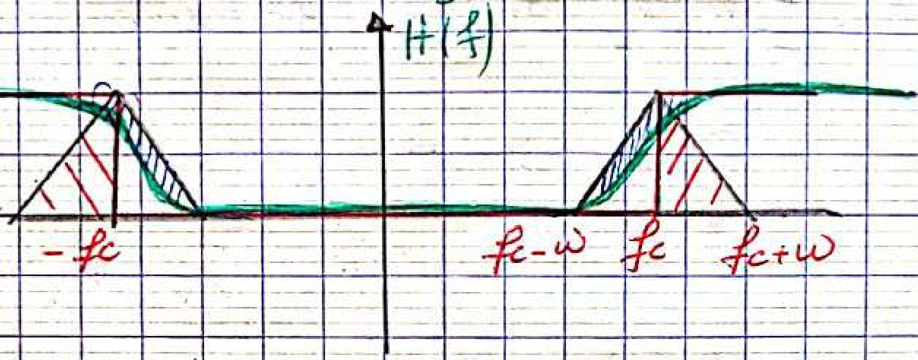
$\oplus \; g(t) \Rightarrow G(f) = G_1(f) + G_2(f)$

$m_2(t) \longrightarrow \boxed{SSB.S} \xrightarrow{+} \oplus$



Chapitre 6 : Modulation à Bande latérale atténuée : Vestigial side Band VSB

Le Filtre en rouge n'est pas realisable dans L'electronic analogique ce qui pousse a avoir le vert



VSB : télévision

condition de $H(f)$:

$$\boxed{H(f-fc) + H(f+fc) = 1}$$

$$G_{VSB}(f) = \frac{Ac}{2}\left(M(f-fc) + M(f+fc)\right) \cdot H(f)$$

$$G_c(f) = \begin{cases} G(f-fc) + G(f+fc) & |f| < w \\ & |f| > w \end{cases}$$

$$G_{VSB}(f) = \frac{Ac}{2}\left(M(f-fc) + M(f+fc)\right) \cdot H(f)$$

on remplace dans

$$G_{VSB}(f) = \frac{Ac}{2}\left(M(f-2fc) + M(f)\right) \cdot H(f-fc)$$

$$+ \frac{Ac}{2}\left(M(f) + M(f+2fc)\right) \cdot H(f+fc)$$

$$= \frac{Ac}{2} M(f)\left(H(f-fc) + H(f+fc)\right) +$$

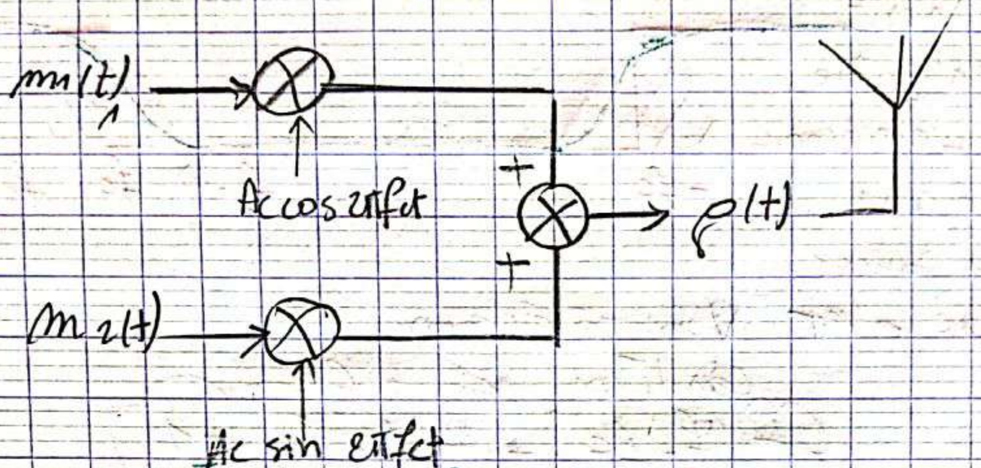
$$\frac{Ac}{2} M(f-2fc) H(f-fc) + \frac{Ac}{2} M(f+2fc) H(f+fc)$$

$$G_c(f) = \begin{cases} \frac{Ac}{2} M(f)\left(H(f-fc) + H(f+fc)\right) & |f| < w \\ 0 & \text{ailleurs} \end{cases}$$

Modulation d'amplitude en quadrature QAM.

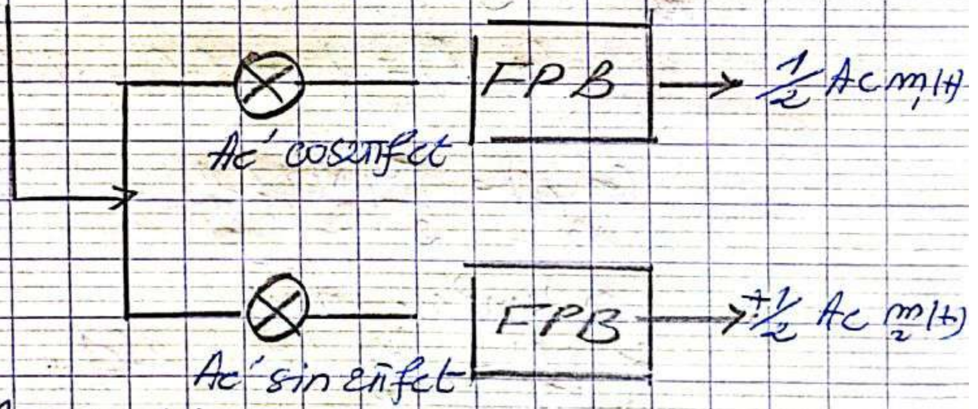
On va transmettre deux msg $m_1(t)$, $m_2(t)$

$\rightarrow [-W, W]$ même porteuse.



Demodulation Coherante (synchrone).

$g(t) = A_c m_1(t) \cos 2\pi f_c t + A_c m(t) \sin 2\pi f_c t$.

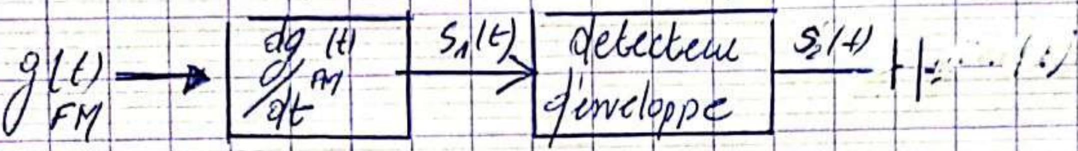


$g_c(t) = A_c m_1(t)$

$g_s(t) = - A_c m_2(t)$

Scanné avec CamScanner

Démodulation FM par discrimination :



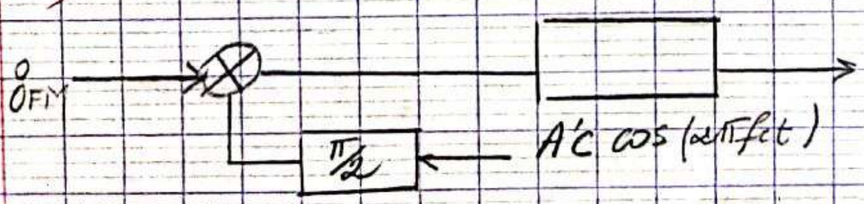
$$g_{FM}(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int m(t)\,dt\right).$$

$$e_n(t) = \frac{dg_{FM}}{dt} = -A_c \sin\left(2\pi f_c t + 2\pi k_f \int m(t)\,dt\right)\left(2\pi f_c + 2\pi k_f\, m(t)\right)$$

$$= \underbrace{-A_c\, 2\pi f_c}\left(1 + \frac{k_f}{f_c}\, m(t)\right) \sin\left(2\pi f_c t + 2\pi k_f \int m\, dt\right)$$

$$= A_c'\left(1 + k_{am}\, m(t)\right) \sin\left(2\pi f_c t + 2\pi k_f \int m(t)\,dt\right)$$

2) Démodulateur en quadrature : ($\pi/2$)



$G_c(f) = \frac{A_c}{2} M(f) \Rightarrow g_c(t) = \frac{A_c}{2} m(t)$.

$G_s(f) = j\left(\overline{G(f-f_c)} - G(f+f_c)\right)$

$G_s(f) = \frac{A_c}{2}\left(M(f-f_c) + M(f+f_c)\right) H(f)$

$G_s(f) = \frac{jA_c}{2}\left(M(f-2f_c) + M(f)\right) \cdot H(f-f_c)$

$- j\frac{A_c}{2}\left(M(f+2f_c) + M(f)\right) \cdot H(f+f_c)$

BF $= j\frac{A_c}{2} M(f)\left(H(f-f_c) - H(f+f_c)\right)$

$+ j\frac{A_c}{2}\left(M(f-2f_c) \cdot H(f-f_c)\right) -$

$j\frac{A_c}{2}\left(M(f+2f_c) \cdot H(f+f_c)\right)$

Du coup

$G_s(f) = \begin{cases} j\frac{A_c}{2} M(f)\left(H(f-f_c) - H(f+f_c)\right) & |f| \leq W \\ 0 & \text{ailleur} \end{cases}$

$\Rightarrow g_s(t) = TF^{-1}[G_s(f)] = m_s(t)$

Donc

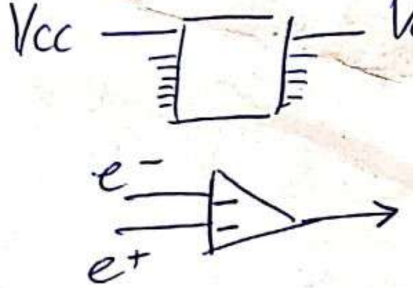
$g_{VSB}(t) = \frac{A_c}{2} m(t) \cos 2\pi f_c t - \frac{A_c}{2} \sin 2\pi f_c t \; m_s(t)$

Chapitre 06 : Les composantes d'une chaîne de transmission

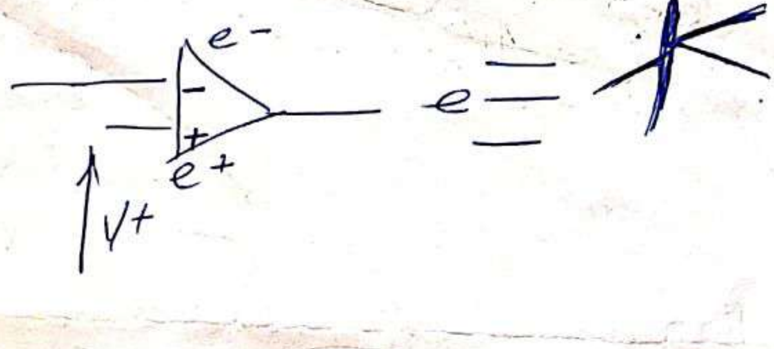
- Amplification / Attenuation
- Filtrage.
- Generation de la porteuse.

L'amplification opérationnel (Ampli op)

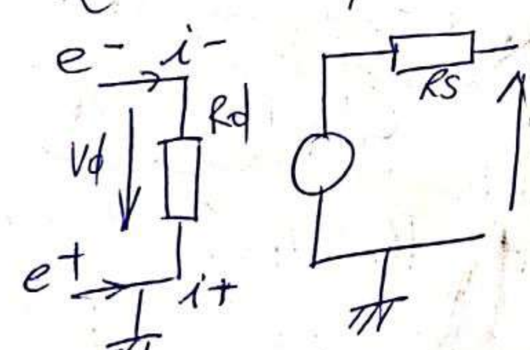
C'est un circuit integré



e^+ : entreé non inverseuse.
e^- : " inverseuse.



Le circuit equivalent

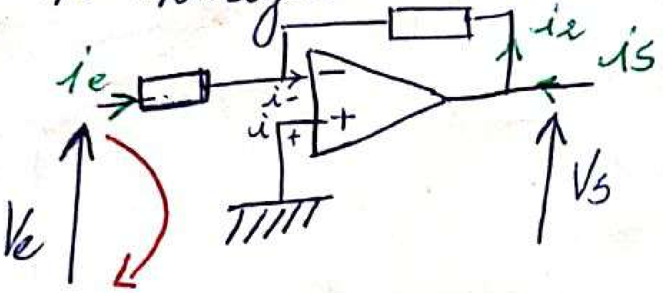


$V_d = e^+ - e^-$: tension differentielle
A_d = gain
R_d = Resistance d'entreé
R_s = Resistance de sortie.

Ampli ideal

$A_d \to$ trés elevé (∞)
$R_d \to$ trés grande (∞).
$i^+ = 0$ $\quad V_d = 0$
$i^- = 0$
R_s (trés petite ($0\,\Omega$))

1. Montage Inverseur :



$V_e - R_1 i_e + V_d = 0$

$\Rightarrow \boxed{V_e = R_1 i_e - \cancel{V_d}^{\,0} = R_1 i_e}$

$i^- = i_2 + i_e = 0$

$\boxed{i_e = -i_2}$

$V_s - R_2 i_2 + V_d = 0$

$\boxed{V_s = R_2 i_2}$

$V_s = -R_2 i_e \Rightarrow \boxed{V_s = \dfrac{-R_2}{R_1} V_e}$

OR $V_e = R_1 i_e$

$$\boxed{\frac{V_s}{V_e} = \frac{-R_2}{R_1}}$$

Exemple :

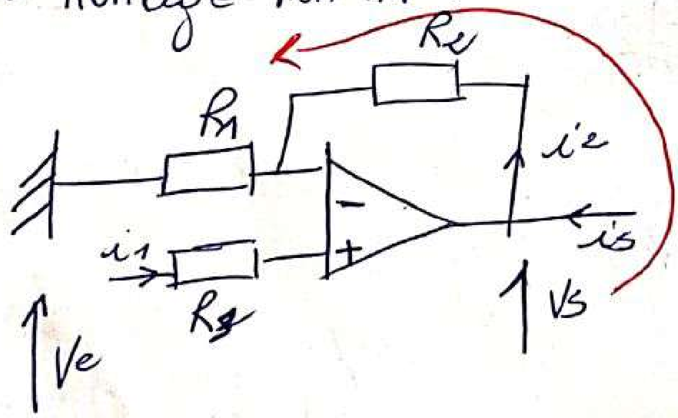
$V_e = 10\,mV$

$R_1 = 10\,k\Omega$

$R_2 = 1\,M\Omega$

$\boxed{V_s = -1\,V}$

2. Montage non inverseur.



$V_s = R_2 i_2 - R_1 i_1$

$i^- = i_2 - i_1 \Rightarrow i_2 = i_1$

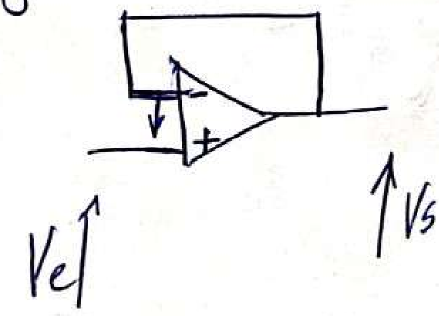
$\boxed{V_s = (R_1 + R_2)\, i_2}$

$V_e = R_1 i_1 \quad V_e = R_1 i_2$

$$V_s = \frac{R_1 + R_2}{R_1} V_e$$

$$\frac{V_s}{V_e} = \left(1 + \frac{R_2}{R_1}\right)$$

3- Montage Suiveur:



$$V_s = -\overset{0}{\cancel{V_d}} + V_e$$

$$V_s = V_e.$$

→ Utilisation Adaptation d'impedance. (Ampli suiveur ▷ impedance d'entrée ∞).

Modulation de fréquence

$$m(t) \longrightarrow \boxed{FM} \longrightarrow g_{FM}(t)$$

$$\uparrow$$

$$A_c \cos 2\pi f_c t$$

$$g(t) = A_c \cos(2\pi \underset{\text{freq instantanée}}{f(t)}\, t).$$

la fréquence varie dans le temps. $f(t)$ est message.

$\cos(\theta) \rightarrow \cos(2\pi f_0 t)$ f est constante

$\cos(\omega_0 t)$ $\quad \omega_0 = 2\pi f_0$.

$$\theta = \int \omega(t)\, dt$$

si $\omega = C^{te} = \omega_0 \rightarrow \omega_{(\theta)} = \cos \int 2\pi f_0 dt =$

$= \cos(2\pi f_0 t)$.

$m(t) \longrightarrow$ porté par f_c.

$$f(t) = f_c + k_f\, m(t).$$

k_f = sensibilité du modulateur

$$g(t) = A_c \cos(\theta(t))$$

$$= A_c \cos\left(\int 2\pi (f_c + k_f\, m(t))\right)$$

$$= A_c \cos\left(\int 2\pi f_c\, dt + \int 2\pi k_f\, m(t)\, dt\right).$$

$$g_{FM}(t) = A_c \cos(2\pi f_c t) + 2\pi k_f \int m(t)\, dt).$$

Cas particulier :

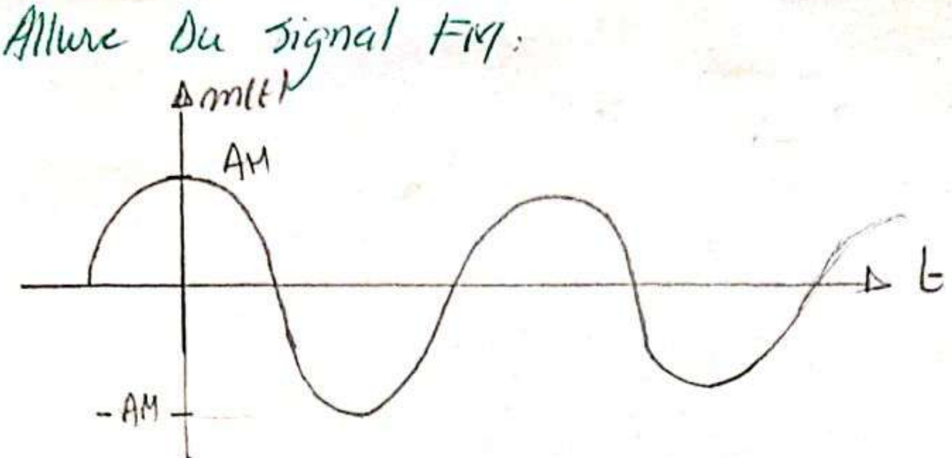
$m(t) = A_m \cos 2\pi f_m t$.

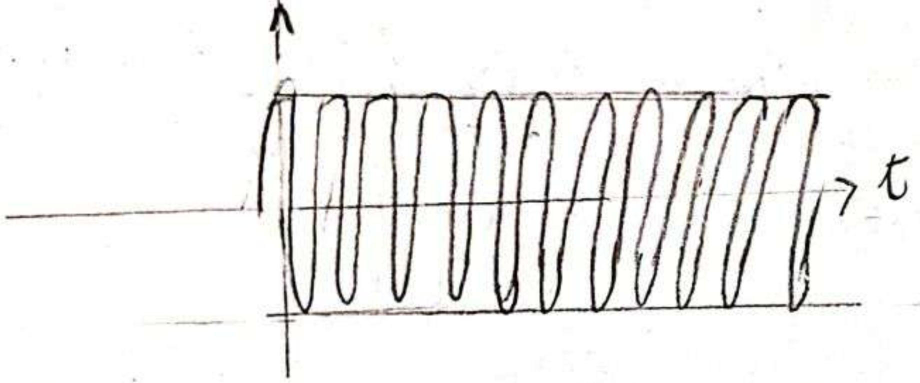
$$g(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int A_m \cos 2\pi f_m t\, dt\right).$$

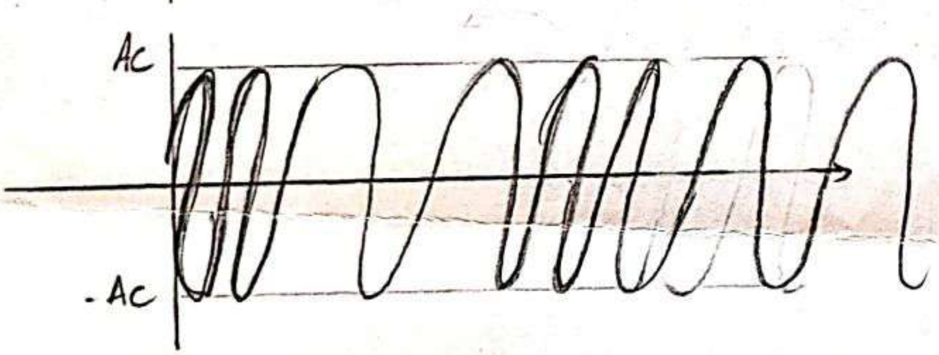
$$= A_c \cos\left(2\pi f_c t + k \frac{A_m 2\pi}{2\pi f_m} \sin 2\pi f_m t\right)$$

$$g_{FM}(t) = A_c \cos\left(2\pi f_c t + \frac{k_f A_m}{f_m} \sin 2\pi f_m t\right).$$

Allure Du Signal FM:







$$f(t) = f_c + k_f\, m(t) \longrightarrow f_c + k_f A_M \cos 2\pi f_m t$$

$$= f_c + \Delta f\, m(t) \quad , \quad \Delta f = k_f \cdot A_m$$ excursion en fré

$$f_c - \Delta f \leq f(t) \leq f_c + \Delta f .$$

$$g_{FM}(t) = A_C \cos\left(2\pi f_c t + \overbrace{\frac{\Delta f}{f_m}}^{\beta} \sin 2\pi f_m t\right).$$

$$g_{FM}(t) = A_c \cos\left(\overbrace{2\pi f_c t}^{a} + \overbrace{\beta \sin 2\pi f_m t}^{b}\right)$$

β indice de Modulation

$$g_{FM}(t) = A_c \cos(2\pi f_c t) \cdot \cos(\beta \sin 2\pi f_m t) - A_c \sin 2\pi f_c t \; \sin(\beta \sin 2\pi f_m t) .$$

1^{er} cas : $\beta \ll 1$

mod FM à bande laterale etroite

$\beta \cdot \sin 2\pi f_m t \ll 1$.

si $\begin{cases} \sin x = x \\ x = \beta \sin 2\pi f_m t. \\ \cos x = 1 \end{cases}$ Developpement de Tylor.

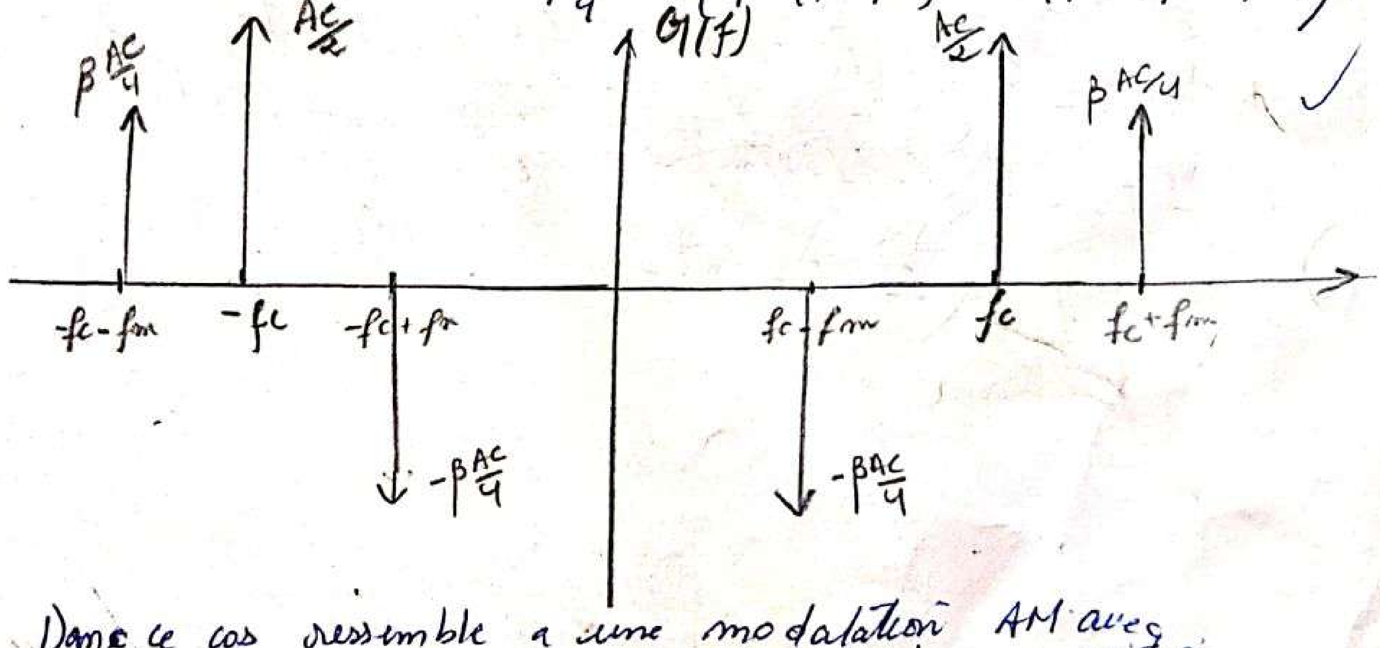
$$\boxed{g_{FM}(t) = A_c \cos(2\pi f_c t) - A_c \beta \sin 2\pi f_c t \cdot \sin 2\pi f_m t}$$

$\Rightarrow g(t) = A_c \cos 2\pi f_c t$

$= \beta \frac{A_c}{2} \left(\cos 2\pi (f_c - f_m) \right) - \cos \left(2\pi (f + f_m) \right)$

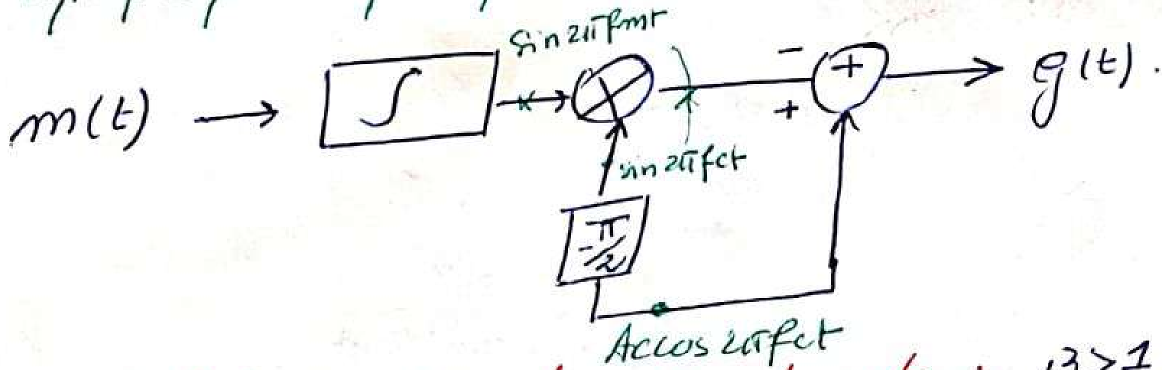
$= A_c \cos 2\pi f_c t + \beta \frac{A_c}{2} \cos\left(2\pi (f_c + f_m) t \right) - \beta \frac{A_c}{2} \cos\left(2\pi (f_c - f_m \right.$

$$G(f) = \frac{A_c}{2} \left(\delta(f - f_c) + \delta(f + f_c) \right) + \beta \frac{A_c}{4} \delta(f - (f_c + f_m) + \delta(f + (f_c + f_m)) - \beta \frac{A_c}{4} \delta(f - (f_c - f_m) + \delta(f + (f_c - f_m))).$$



Dans ce cas ressemble a une modulation AM avec porteur (Bande laterale sup et infer) en opposition de phase.

Synoptique de Generation



Modulation FM à langue bande : $\beta > 1$

$$g(t) = A_c \cos(2\pi f_c t) \cdot \cos(\beta \sin 2\pi f_m t) - A_c \sin(2\pi f_c t)(\sin(\beta \sin 2\pi f_m t)$$

Analyse de Bessel :

$$g_{FM}(t) = A_c \sum_{-\infty}^{+\infty} J_n(\beta) \cos(2\pi(f_c - n f_m t))$$

$$= A_c J_0(\beta) \cos(2\pi f_c t) + \cdots$$

$$A_c J_1(\beta) \cos(2\pi(f_c - f_m) t) + A_c J_2(\beta) \cos(2\pi(f_c - 2f_m) t) + \cdots$$

$$A_c J_{-1}(\beta) \cos(2\pi(f + f_m) t) + A_c J_{-2}(\beta) \cos(2\pi(f_c + 2f_m) t) + \cdots$$

$$G(f) = \frac{A_c}{2} J_0 [\delta(f - f_c) + \delta(f + f_c)] \quad -(f - (f_c - f_m)) \quad -f_c + f_m$$

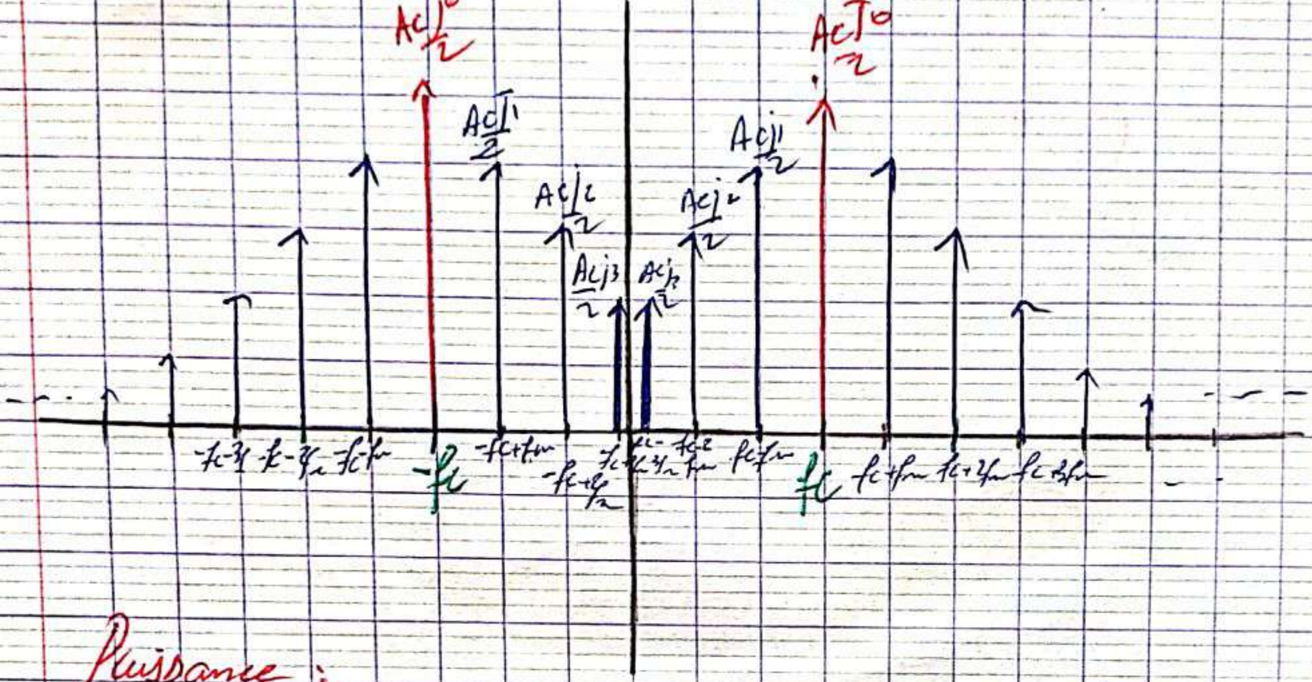
$$+ \frac{A_c}{2} J_1 [\delta(f - (f_c - f_m)) + \delta(f + (f_c - f_m))]$$

$$+ \frac{A_c}{2} J_2 [\delta(f - (f_c - 2f_m)) + \delta(f + (f_c - 2f_m))].$$

$$+ \frac{A_c}{2} J_{-2} [\delta(f - (f_c + 2f_m)) + \delta(f + (f_c + 2f_m))].$$

$$+ \frac{A_c}{2} J_{-1} [\delta(f - (f_c + f_m)) + \delta(f + (f_c + f_m))]$$

$n<0$



Puissance :

$$P = \frac{V^2}{R} \_ \frac{V}{R}.$$

$$g_{FM}(t) = A_c \sum_{-\infty}^{+\infty} \left[J_n \cos\left(2\pi\left(f_c - n f_m\right)t\right)\right].$$

$$P = \frac{A_c^2}{2R}.$$