V. AMPLITUDE MODULATION (A.M) DAN ANALISA FM

1. Amplitude Modulation (A.M)

Proses modulasi dimana amplituda gelombang pembawa berubah-ubah sesuai dengan gelombang modulasi (informasi), dengan frekuensi tetap.

$$\ell\,(t) = (E_C + k\,E_m\,Sin\,\omega_m t)\,Sin\,\omega_C t$$

$$= E_C\,(1 + \frac{k\,E_m}{E_C}\,Sin\,\omega_C t$$

k $\frac{E_m}{E_C} = m = indeks\ modulasi$

$= kedalaman\ modulasi$

Sehingga :

$$\ell\,(t) = E_C\,(1 + m\,Sin\,\omega_C t)\,Sin\,\omega_C t$$

$$= E_C\,Sin\,\omega_C t + m\,E_C\,Sin\,\omega_m t\,Sin\,\omega_C t$$

$*\quad \sin x \sin y = \frac{1}{2}\,[\cos(x-y) - \cos(x+y)]$

$$\therefore\ \ell\,(t) = E_C\ Sin\,\omega_C t + \frac{mE_C}{2}\cos(\omega_C\omega_m)t$$

$$- \frac{mE_C}{2}\cos(\omega_C\omega_m)t$$

$E_C\,Sin\,\omega_C t = komponen\ gelombang\ pembawa$

$\frac{mE_C}{2}\cos(\omega_C\omega_m)t = komponen\ gelombang\ sisi\ bawah\ (LSB)$

$\frac{mE_C}{2}\cos(\omega_C\omega_m)t = komponen\ gelombang\ sisi\ atas\ (USB)$

Perbandingan daya dalam A.M

$$P_t = P_C + P_{USB} + P_{LSB}$$

$$= \frac{\left(Ec/\sqrt{2}\right)^2}{R} + \left(\frac{m\,Ec}{2.\sqrt{2}}\right)^2\Big/R + \left(\frac{m\,Ec}{2\,\sqrt{2}}\right)^2\Big/R$$

$$P_C = \frac{{E_C}^2}{2.R}$$

$$P_{USB} = P_{LSB} = \frac{m^2{E_C}^2}{8R}$$

$$P_t = \left\{1 + \left(\frac{m}{2}\right)^2\right\}P_C$$

$$\frac{P_t}{P_C} = 1 + \left(\frac{m}{2}\right)^2$$

2. Analisis FM

$X_C\ (t) = R_C\ \cos \omega_C t + Q$ (PEMBAWA)

$X_m\ (t) = A_m\ \cos \omega_m t$ (INFORMASI)

Dimodulasi FM : $X_C\ (t) = A_C\ \cos \theta(t) + Q$

Tanpa informasi :

$$\theta(t) = \omega_C t \quad \rightarrow \quad \omega_C = 2\pi\, f_e . t$$

$$d\ \theta(t) = 2\pi\, f_C . dt$$

$$\frac{d\ \theta(t)}{2\pi\ dt} = f_C$$

Saat ada informasi :

$$\frac{d\ \theta(t)}{2\pi . dt} = f_C + k\ . X_m t$$

$$\int d\theta\ (t) = \sqrt{2\pi\ f_C\ dt} + \sqrt{2\pi . k\ A_m \cos \omega_m t\ dt}$$

$$\theta(t) = 2\pi\ f_C\ t + \frac{2\pi . k . A_m}{\omega_m} \sin \omega_m t$$

$$\theta(t) = \omega_C\ t + \frac{k\ . A_m}{f_m} \sin \omega_m t$$

Dimana : $\frac{k\ . A_m}{f_m} = I_X = INDEX\ MODULASI$

$k\ . A_m = \Delta f = DEVIASI\ FREKUENSI$

$k = konstanta \left[{}^{Hertz}/_{Volt}\right]$

Sehingga fungsi gelombang FM menjadi

$$X_C\ (t) = A_C . \cos\ (\omega_C t + I_X\ \sin \omega_m\ t) + Q$$

Ingat fungsi goneometri

$\cos(\alpha + \beta) = \cos x \cos \beta - \sin x \sin \beta$

Jadi : $X_C\ (t) = A_C\,\{ cos\ \omega_C t\,.\cos\ (I_X\ \sin\omega_m\ t) - sin\ \omega_C t\,.\sin\ (I_X\ \sin\omega_m\ t)$

<u>Sesuai uraian fungsi Bessel</u>

$\cos\ (I_X\ \sin w_m\ t) = J_o\ (I_X) + 2\,J_2\ (I_X)\cos 2\ \omega_m t$

$+ 2\,J_4\ (I_X)\cos 4\ \omega_m t + \cdots$

$+ 2\,J_{m.2.}\ (I_X)\cos 2n\ \omega_m t$

$\sin\ (I_X\ \sin w_m\ t) = 2\,J_1\ (I_X)\sin\ \omega_m t +$

$2\,J_3\ (I_X)\sin 3\ \omega_m t + \cdots$

$+ 2\,J_{2.m-1}\ (I_X)\sin(2n-1)\ \omega_m t$

Ingat : $\cos A\cos B = {}^1/_2\cos\ (A-B) + \frac{1}{2}\cos\ (A+B)$

$\sin A\sin B = {}^1/_2\sin\ (A-B) + \frac{1}{2}\sin\ (A+B)$

Sehingga : $X_C\ (t) = A_C\,\{J_o\ (I_X)\ cos\ \omega_C t + \cos\omega_C t\ [2\,J_2\ (I_X)\cos 2n\ \omega_m t +$

$..... + 2\,J_{2n}\ (I_X)\cos 2n\ \omega_m t]$

$-\sin\omega_C t\ [+\ 2\,J_1\ (I_X)\sin\omega_m t + 2J_m - 1\ (I_X)\sin(2n-1)\omega_m t]$

<u>Diuraikan :</u>

$X_C t = A_C J_o(I_X)\cos\omega_C t +$

$A_C J_1(I_X)\cos(\omega_C - \omega_m)t -$

$A_C J_1(I_X)\cos(\omega_C + \omega_m)t +$

$A_C J_2(I_X)\cos(\omega_C - 2\omega_m)t +$

$A_C J_2(I_X)\cos(\omega_C + 2\omega_m)t +$

$A_C J_3(I_X)\cos(\omega_C - 3\omega_m)t -$

$A_C J_3(I_X)\cos(\omega_C + 3\omega_m)t + \cdots$

$A_C J_{2n}(I_X)\cos(\omega_C - 2n\omega_m)t +$

$A_C J_{2n}(I_X)\cos(\omega_C + 2n\omega_m)t +$

$A_C J_{2n-1}(I_X)\cos(\omega_C - (2n-1)\omega_m)t -$

$A_C J_{2n-1}(I_X)\cos(\omega_C + (2n-1)\omega_m)t\ .$

Dimana : J = KONSTANTA BESSEL (lihat tabel)

B = LEBAR BIDANG

Dari tabel dapat ditentukan banyaknya atau jumlah 'SIDE BAND' (n).

$$n = I_X + 1$$

Sehingga lebar bidang (B) menjadi :

B = $2\,(I_X + 1)\,f_m$ atau

B = $2\left(\frac{kA_m}{f_m} +\right) f_m \;\rightarrow\; kA_m = \Delta f$

B = $2\,(\Delta f_m + f_m)$

Dari analisis FM dapat dihitung daya rata-rata :

P = $P_C\left({J_o}^2 + 2\sum_{m=1}^{\sim} {J_m}^2\right)$

Dimana : P_C = daya pancar

P = daya pancar total efektif

Karena : ${J_o}^2 + 2\sum_{m=1}^{\sim} {J_m}^2 = 1$

Maka : P = P_C

Bila jumlah 'SIDE BAND (n)' diambil :

$n = I_X + 1$, maka n = I_X

Dan untuk $I_X > 1$, maka $n = I_X$

Sehingga : B = $2\,\Delta f$ (pendekatan)

MODULATOR REAKTANSI

$eg = ig.R = \frac{R}{R-jX_C}.e$ .... (1)

$X_C \gg R$

Arus drain FET (i) :

$i = g_m.e_g = g_m\frac{R.e}{R-jx_C}$ .... (2)

Impedansi antara A-A (Z) :

$$Z = \frac{e}{i} = \frac{e}{g_m.\frac{R.e}{R-jX_C}} = \frac{R-j\,X_C}{g_m.R}$$

$atau \quad Z = \frac{1}{g_m}\left(1 - j\frac{X_C}{R}\right)$ .... (3)

Untuk $X_C \gg R$ persamaan (3) dapat disederhanakan menjadi :

$Z = -j\frac{X_C}{g_m .R}$ .... (4)

Atau $X_{eq} = \frac{X_C}{g_m .R} = \frac{1}{2\,\pi\, f .g_m .R .C} = \frac{1}{2\,\pi\, f\, .C_{eq}}$

Jadi $\boxed{C_{eq} = g_m .R .C}$ .... (5)

Dimana : $g_m = transkonduktansi\ FET$

untuk $X_C = n.R$ pada rangkaian (Kapasitif) reaktansi RC dengan FET :

$X_C = \frac{1}{WC} = n.R$

$C = \frac{1}{Wn .R} = \frac{1}{2\pi f .n .R}$, dari persamaan (5)

$\therefore\ C_{eq} = gm.R.C = \frac{gm.R}{2\pi f .n .R}$

$\boxed{C_{eq} = \frac{gm}{2\pi f .n}}$ .... (6)

NAMA	Z_{gd}	Z_{gs}	SYARAT	REAKTANSI
R-C KAPASITIF	C	R	$X_c \gg R$	$C_{eq} = gm.R.C$
R-C INDUKTIF	R	C	$R \gg X_C$	$L_{eq} = \frac{R.C}{gm}$
R-L INDUKTIF	L	R	$X_L \gg R$	$L_{eq} = \frac{L}{gm.R}$
R-L KAPASITIF	R	L	$R \gg X_L$	$C_{eq} = \frac{gm.L}{R}$

<u>MULTIPLEXING</u>

(1) FDM (Frequency Division Multiplex)
(2) TDM (Time Division Multiplex)

(1) FDM
   a) LANGSUNG (DIRECT)
   b) BERTINGKAT (MULTI STAGE MODULATION)

<u>Group dalam modulasi bertingkat</u>

1. PRE-GROUP 3x1 = 3 kanal
2. BASIC-GROUP 3x4x1 = 12

3. BASIC SUPERGROUP 3x4x5 = 60
4. BASIC MASTER GROUP 3x4x5x5 = 300
5. BASIC SUPER-MASTER GROUP 3x4x5x5x3 = 900
6. BASIC JUMBO GROUP 3x4x5x5x3x4 = 3600

Time division multiplex

Original standard dari British Post Office, yaitu dengan :

- 24 TDM channels
- Sampling rate 8000 periode / sekon ($f_c \geq 2B$
- 8 pulse / sampling (7 standard level dan 1 pulsa sinkronisasi)
- Lebar pulsa 0.625 μs

Dengan demikian :

- Jarak interval antar sample = $\frac{1}{8000}$ = 125 μs
- Waktu untuk setiap group pulsa = 0.625 μs x 8 = 5 μs
- Sehingga waktu seluruhnya = 24 x 8 μs 120 μs

Frekuensi pembawa – group

- PRE GROUP : 12, 16, 20 KHz. (USB)
- BASIC GROUP : 84, 96, 108, 120 KHz. (LSB)
- BASIC SUPER GROUP : 612 KHz, 564 KHz, 516 KHz, 468 KHz, 420 KHz.
- BASIC MASTER GROUP : 1364 KHz, 1612 KHz, 1860 KHz, 2106 KHz, 2356 KHz.
- BASIC SUPER MASTER GROUP : 10560 KHz, 11880 KHz, 13200 KHz.
- BASIC JUMBO GROUP : 12704 KHz, 16720 KHz. (LSB)

38620 KHz. (USB)