Lecture 2

幅度调制 I
Amplitude Modulation

Lecture 2 Amplitude Modulation

□**载波调制(*Carrier Modulation*):**
将载波变换为一个载有信息的已调信号

□**解调(*De-Modulation*):**
接收端从已调信号中恢复基带信号

Lecture 2 Amplitude Modulation

- 模拟调制
  - 幅度调制 (线性调制) (*AM*)
    - 常规双边带调幅(*Standard Amplitude Modulation*)
    - 抑制载波双边带调幅(*Double-Side Band,DSB*)
    - 单边带调幅(*Single-Side Band,SSB*)
    - 残留边带调幅(*Vestigial-Side Band,VSB*)
  - 频率调制 FM
  - 相位调制 PM
  - 频率调制 FM、相位调制 PM：角度调制 (非线性调制)

Lecture 2 Amplitude Modulation

□**常规双边带调幅(*Standard AM*)**
- ♦时域表达
- ♦调制过程
- ♦频域表达
- ♦解调过程
- ♦功率分配

□双边带调幅***(Double-Side Band,DSB)***
□单边带调幅***(Single-Side Band,SSB)***
□残留边带调幅***(Vestigial-Side Band,VSB)***

Standard AM的时域表示

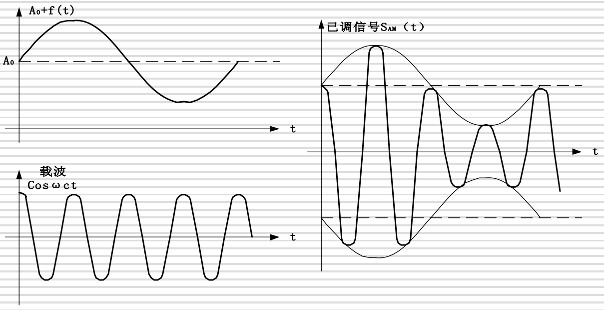
□ 幅度调制:用基带信号*f(t)*去迫使高频载波的瞬时幅度随*f(t)*的变化而变化

□ Standard AM:

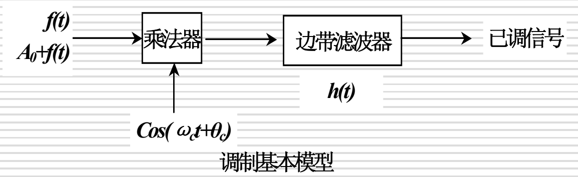
$$S_{AM}(t)=\left[A_0+f(t)\right]\cos\left(\omega_c t+\theta_c\right)$$

其中 ω_c为载波角频率
θ_c为载波起始相位
A_0为载波幅度

Standard AM时域波形

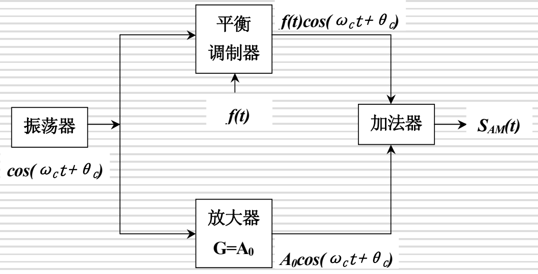


标准调幅的调制过程



调制基本模型

标准调幅的调制过程



标准调幅波的调制器

AM信号的频域表示

$$S_{AM}(t)=\left[A_0+f(t)\right]\cos\left(\omega_c t+\theta_c\right)$$

$$=\left[A_0+f(t)\right]\cdot\left[\frac{e^{j(\omega_c t+\theta_c)}+e^{-j(\omega_c t+\theta_c)}}{2}\right]$$

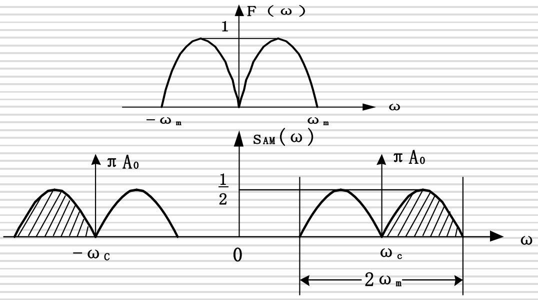
$$S_{AM}(\omega)=\left[2\pi A_0\delta(\omega-\omega_c)+F(\omega-\omega_c)\right]\frac{e^{j\theta_c}}{2}$$

$$+\left[2\pi A_0\delta(\omega+\omega_c)+F(\omega+\omega_c)\right]\frac{e^{-j\theta_c}}{2}$$

$$令\theta_c=0\Rightarrow S_{AM}(\omega)=\pi A_0\delta(\omega-\omega_c)+\frac{F(\omega-\omega_c)}{2}$$

$$+\pi A_0\delta(\omega+\omega_c)+\frac{F(\omega+\omega_c)}{2}$$

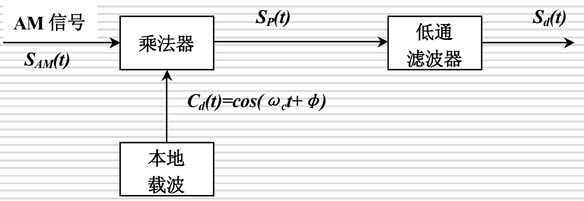
AM信号的频域表示



AM信号的频域表示

- □将$F(\omega)$搬移到载波频率(载频)f_c附近;
- □ $|\omega|\geq\omega_c$ 上边带(USB);
  $|\omega|\leq\omega_c$ 下边带(LSB);
- □ 带宽
  $$B_{AM}=\frac{1}{2\pi}\left[(\omega_c+\omega_m)-(\omega_c-\omega_m)\right]=2f_m=2B$$
- □两个冲激

AM解调—相干解调



相干解调器

相位相干(**Phase-coherent**)/同步(**Synchronous**)

相干解调：同步（相位差问题）

- □ 乘法器的输入:

  $S_{AM}(t)=[A_0+f(t)]cos(\omega_c t+\theta_c)$

  $C_d(t)=cos(\omega_c t+\phi)$

- □ 乘法器的输出:

  $S_p(t)=S_{AM}(t)\,C_d(t)$

  $=[A_0+f(t)]cos(\omega_c t+\theta_c)cos(\omega_c t+\phi)$

  $=[A_0+f(t)][cos(\theta_c-\phi)+cos(2\omega_c t+\theta_c+\phi)]/2$

- □ 用*LPF*滤除2ω_c的分量:

  $S_d(t)=\{[A_0+f(t)]cos(\theta_c-\phi)\}/2$

相干解调：同步（频率差问题）

- □ 本地载波

  $C_d(t)=cos(\omega_c t+\Delta\omega t+\theta_c)$

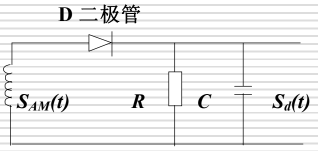
- □ 输出

  $S_d(t)=\{[A_0+f(t)]cos\Delta\omega t\}/2$

- □ 锁相环技术

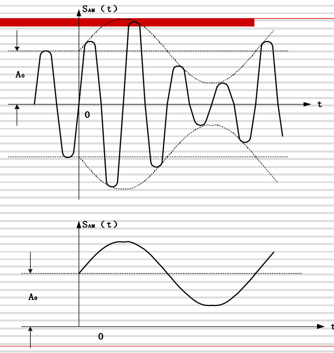
AM解调--非相干解调

包络检波(*Envelope Detection*)



$S_d(t)\approx A_0+f(t)$

AM解调--非相干解调



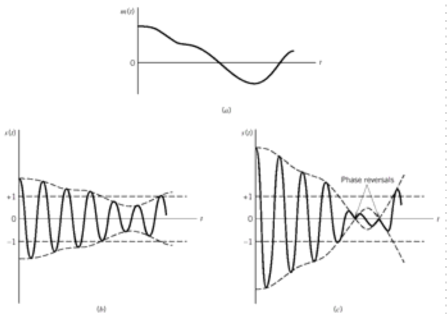
AM解调--非相干解调

为防止过调制的出现必须

$A_0+f(t)\geq 0$

即

$|f(t)|_{max}\leq A_0$



AM调制功率分配

- □调制效率

AM信号的总平均功率为

$$P_s=\overline{S_{AM}^2(t)}=\overline{[A_0+f(t)]^2cos^2\omega_c t}$$

$$=\overline{A_0^2cos^2\omega_c t}+\overline{f^2(t)cos^2\omega_c t}+\overline{2f(t)A_0cos^2\omega_c t}$$

*f(t)*无直流分量

$$\therefore\ \overline{f(t)}=0$$

$$\cos^2\omega_c t=\frac{1}{2}(1+\cos 2\omega_c t),\ \ 而\overline{\cos 2\omega_c t}=0\Rightarrow\overline{\cos^2\omega_c t}=\frac{1}{2}$$

AM调制功率分配

$$\therefore P_S = \frac{A_0^2}{2} + \frac{\overline{f^2(t)}}{2} = P_C + P_{SB}$$

调制效率$\eta_{AM} = \frac{P_{SB}}{P_{AM}} = \frac{P_{SB}}{P_{SB}+P_C} = \frac{\overline{f^2(t)}}{A_0^2 + \overline{f^2(t)}}$

避免过调幅现象出现，必须

$$|f(t)|_{max} \le A_0$$

$$\therefore \eta_{AM} \le 50\%$$

AM调制功率分配

- □ 正弦单频调制情况

$f(t)=A_m cos\ \Omega t$

$$S_{AM}(t) = [A_0 + A_m \cos\Omega t]\cos(\omega_c t + \theta_c)$$

$$= A_0[1 + \beta_{AM} \cos\Omega t]\cos(\omega_c t + \theta_c)$$

- □ 调幅指数

$$\beta_{AM} = \frac{|f(t)|_{max}}{A_0} = \frac{A_m}{A_0}$$

- □ 为防止过调制，要求

$$\beta_{AM} \le 1$$

AM调制功率分配

$$S_{AM}(t) = A_0 cos(\omega_c t + \theta_c) + \frac{1}{2}\beta_{AM} A_0 cos[(\omega_c - \Omega)t + \theta_c]$$

$$+\frac{1}{2}\beta_{AM} A_0 cos[(\omega_c + \Omega)t + \theta_c]$$

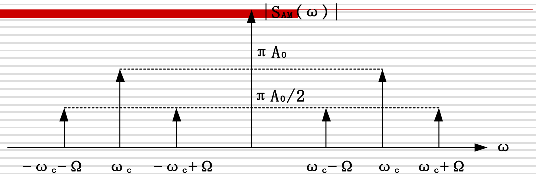
令 θ_c=0

$$S_{AM}(\omega) = \pi A_0[\delta(\omega-\omega_c) + \delta(\omega+\omega_c)]$$

$$+\frac{\pi A_0}{2}[\delta(\omega-\omega_c-\Omega) + \delta(\omega-\omega_c+\Omega)]$$

$$+\frac{\pi A_0}{2}[\delta(\omega+\omega_c-\Omega) + \delta(\omega+\omega_c+\Omega)]$$

AM调制功率分配



$$\eta_{AM} = \frac{\overline{f^2(t)}}{A_0^2 + \overline{f^2(t)}} = \frac{\frac{1}{2}A_m^2}{A_0^2 + \frac{1}{2}A_m^2} = \frac{\beta_{AM}^2}{2 + \beta_{AM}^2}$$

临界状态下 β_{AM}=1 $(\eta_{AM})_{max}$=1/3

Lecture 2 Amplitude Modulation

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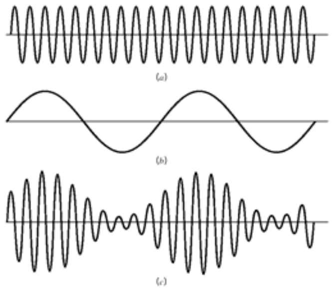
DSB-AM的时域表示

$S_{DSB}(t)$

$=f(t)cos(\omega_c t+\theta_c)$



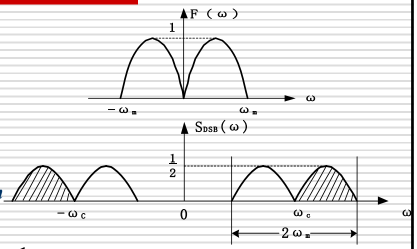
DSB-AM的频域表示

$$S_{DSB}(\omega)=\frac{1}{2}F(\omega-\omega_c)e^{j\theta_c}+\frac{1}{2}F(\omega+\omega_c)e^{-j\theta_c}$$

令$\theta_c=0$

$$=\frac{1}{2}F(\omega-\omega_c)+\frac{1}{2}F(\omega+\omega_c)$$

DSB-AM的频域表示



- □ 线性搬移
- □ USB/LSB
- □ 带宽

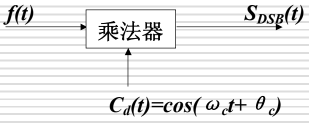
  $B_{DSB}=2B=2f_m$
- □ 调制效率

  $$P_{DSB}=\overline{S_{DSB}^2(t)}=\frac{1}{2}\overline{f^2(t)}=P_{SB}$$

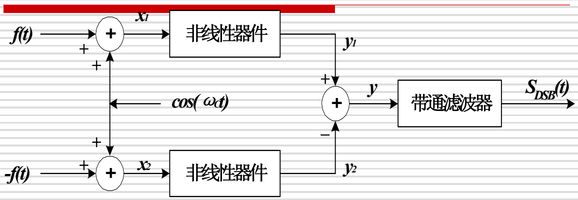
  $$\eta=100\%$$

DSB-AM的调制

- □ $S_{DSB}(t)=f(t)\cos(\omega_c t+\theta_c)$
- □ 乘法器—平衡调制器(*Balanced Modulator*)



DSB-AM的调制



例：若非线性器件的输入-输出特性为:$y=a_1x+a_2x^2$

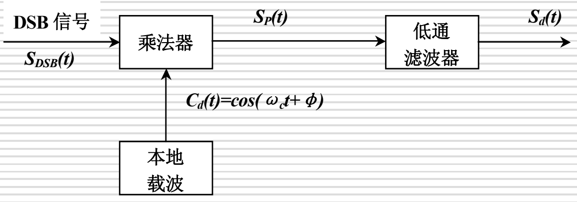
解：由图 $x_1=f(t)+\cos\omega_c t$; $x_2=-f(t)+\cos\omega_c t$

$y_1=a_1[f(t)+\cos\omega_c t]+a_2[f(t)+\cos\omega_c t]^2$

$y_2=a_1[-f(t)+\cos\omega_c t]+a_2[-f(t)+\cos\omega_c t]^2$

$\therefore y=y_1-y_2=2a_1f(t)+4a_2f(t)\cos\omega_c t$ → BPF

DSB的解调--相干解调



相干解调器

$S_d(t)=f(t)\cos(\theta_c-\phi)/2$