Lecture 3

幅度调制 II

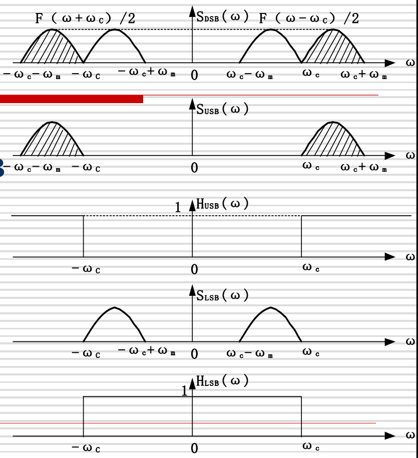
Amplitude Modulation

Lecture 3 Amplitude ModulationII

- 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*)

SSB频域

- SSB—USB/LSB
- $B_{SSB}=f_m=B$
- $\eta=100\%$



SSB频域

- 正负符号函数

$$Sgn(\omega)=\begin{cases}1 & |\omega|>0\\ -1 & |\omega|<0\end{cases}$$

- 以下边带为例

$$S_{DSB}(\omega)=\frac{1}{2}[F(\omega+\omega_c)+F(\omega-\omega_c)]$$

$$H(\omega)=\frac{1}{2}[Sgn(\omega+\omega_c)-Sgn(\omega-\omega_c)]$$

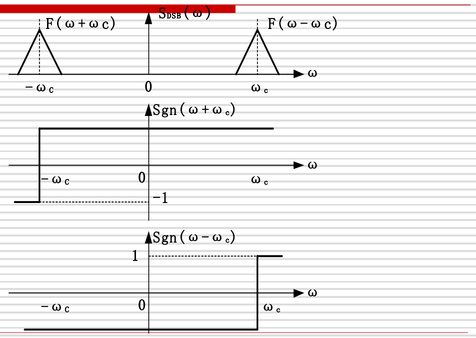
SSB频域

$$\begin{aligned}S_{SSB}(\omega)&=S_{DSB}(\omega)H(\omega)\\ &=\frac{1}{2}[F(\omega+\omega_c)+F(\omega-\omega_c)]\\ &\cdot\frac{1}{2}[Sgn(\omega+\omega_c)-Sgn(\omega-\omega_c)]\\ &=\frac{1}{4}[F(\omega+\omega_c)Sgn(\omega+\omega_c)\\ &+F(\omega-\omega_c)Sgn(\omega+\omega_c)\\ &-F(\omega+\omega_c)Sgn(\omega-\omega_c)\\ &-F(\omega-\omega_c)Sgn(\omega-\omega_c)]\end{aligned}$$

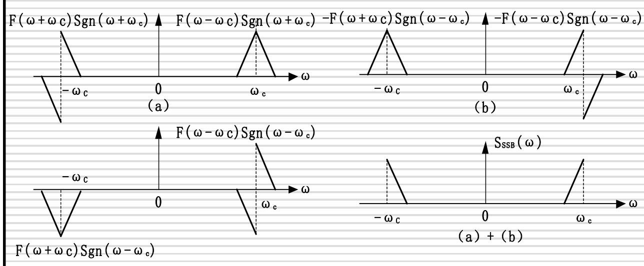
SSB频域

$$\begin{aligned}S_{SSB}(\omega)=&\frac{1}{4}[F(\omega+\omega_c)Sgn(\omega+\omega_c)\\ &-F(\omega-\omega_c)Sgn(\omega-\omega_c)]\\ &+\frac{1}{4}[F(\omega-\omega_c)+F(\omega+\omega_c)]\end{aligned}$$

SSB频域



SSB频域



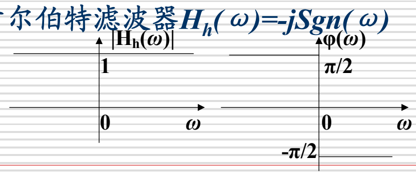
SSB的时域表示

- 希尔伯特(Hilbert)变换

$$\hat f(t)=\frac{1}{\pi}\int_{-\infty}^{\infty}\frac{f(\tau)}{t-\tau}d\tau = \mathcal{H}[f(t)]$$

$$\hat F(\omega)=\mathcal{F}\{\mathcal{H}[f(t)]\}=-jF(\omega)Sgn(\omega)$$

- 希尔伯特滤波器$H_h(\omega)=-jSgn(\omega)$



SSB的时域表示

$$\frac{1}{4}[F(\omega+\omega_c)+F(\omega-\omega_c)]\xrightarrow{\mathcal{F}^{-1}}\frac{1}{2}f(t)\cdot\cos\omega_c t$$

$$\frac{1}{4}[F(\omega+\omega_c)Sgn(\omega+\omega_c)-F(\omega-\omega_c)Sgn(\omega-\omega_c)]$$

$$=-\frac{1}{4j}\{F(\omega+\omega_c)[-jSgn(\omega+\omega_c)]-F(\omega-\omega_c)[-jSgn(\omega-\omega_c)]\}$$

$$=-\frac{1}{4j}[\hat F(\omega+\omega_c)-\hat F(\omega-\omega_c)]\xrightarrow{\mathcal{F}^{-1}}=\frac{1}{2}\hat f(t)\sin\omega_c t$$

SSB的时域表示

$$\therefore S_{LSB}(\omega)\xrightarrow{\mathcal{F}^{-1}}$$

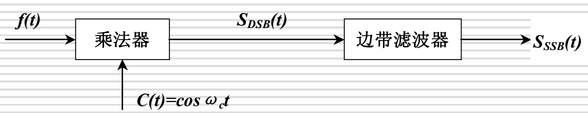
$$S_{LSB}(t)=\frac{1}{2}f(t)\cos\omega_c t+\frac{1}{2}\hat f(t)\sin\omega_c t$$

同理

$$S_{USB}(t)=\frac{1}{2}f(t)\cos\omega_c t-\frac{1}{2}\hat f(t)\sin\omega_c t$$

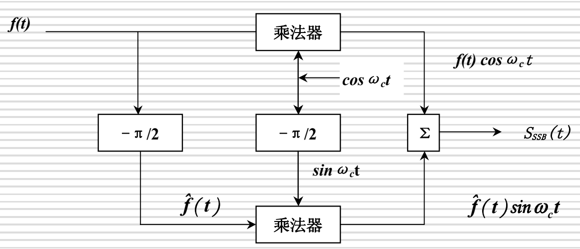
SSB调制—滤波法

$$S_{SSB}(\omega)=S_{DSB}(\omega)H(\omega)$$

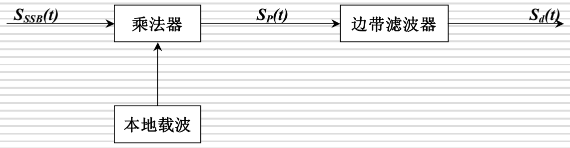


SSB调制—相移法

$$S_{SSB}(t)=f(t)cos\omega_c t\pm\hat{f}(t)sin\omega_c t$$



SSB相干解调



$$S_{SSB}(t)=f(t)\cos\omega_c t\mp\hat{f}(t)\sin\omega_c t$$

$$S_p(t)=S_{SSB}(t)C_d(t)=\left[f(t)\cos\omega_c t\mp\hat{f}(t)\sin\omega_c t\right]\cos\omega_c t$$

$$=\frac{1}{2}f(t)+\frac{1}{2}f(t)\cos 2\omega_c t\mp\frac{1}{2}\hat{f}(t)\sin 2\omega_c t\xrightarrow{LPF}\frac{1}{2}f(t)$$

Lecture 3 Amplitude ModulationII

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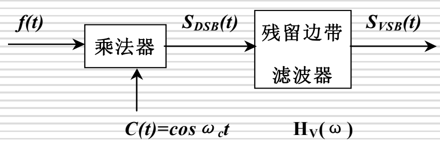
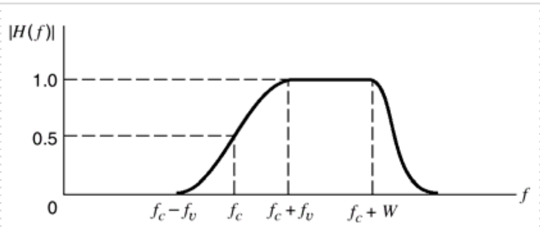
滤波法产生VSB信号

□关键: $H_v(\omega)$的截止特性在$|\omega|=\omega_c$点上相对于1/2幅度点呈奇对称

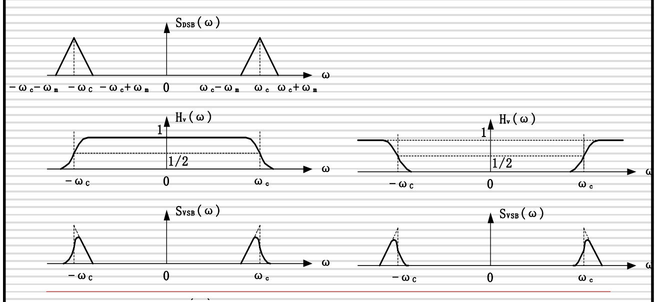


$$S_{VSB}(\omega)=\frac{1}{2}[F(\omega+\omega_c)+F(\omega-\omega_c)]\cdot H_v(\omega)$$

滤波法产生VSB信号



滤波法产生VSB信号

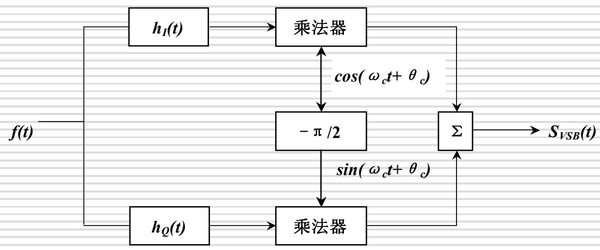


相移法产生VSB信号

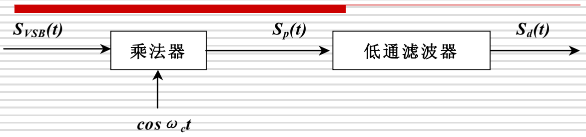
$$S_{VSB}(t)=S_{DSB}(t)*h_v(t)=\left[f(t)\cos\omega_c t\right]*h_v(t)$$
$$=\int_{-\infty}^{\infty}h_v(\tau)f(t-\tau)\cos\omega_c(t-\tau)d\tau$$
$$\cos(\alpha-\beta)=\cos\alpha\cos\beta+\sin\alpha\sin\beta$$
$$S_{VSB}(t)=\left[\int_{-\infty}^{\infty}h_v(\tau)\cos\omega_c\tau\cdot f(t-\tau)d\tau\right]\cos\omega_c t$$
$$+\left[\int_{-\infty}^{\infty}h_v(\tau)\sin\omega_c\tau\cdot f(t-\tau)d\tau\right]\sin\omega_c t$$
$$h_I(t)=h_v(t)\cdot\cos\omega_c t$$
$$h_Q(t)=h_v(t)\cdot\sin\omega_c t$$

相移法产生VSB信号

$$\therefore S_{VSB}(t)=\left[f(t)*h_I(t)\right]\cos\omega_c t+\left[f(t)*h_Q(t)\right]\sin\omega_c t$$



VSB的相干解调



$$S_p(t)=S_{VSB}(t)\cdot\cos\omega_c t$$
$$S_p(\omega)=\frac{1}{2\pi}S_{VSB}(\omega)*C_d(\omega)$$
$$=\frac{1}{2\pi}S_{VSB}(\omega)*\left[\pi\delta(\omega-\omega_c)+\pi\delta(\omega+\omega_c)\right]$$

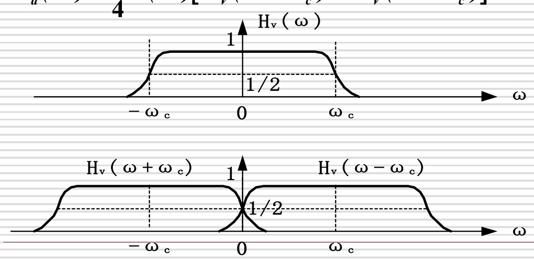
VSB的相干解调

$$S_p(t)=\frac{1}{2}\left[S_{VSB}(\omega-\omega_c)+S_{VSB}(\omega+\omega_c)\right]$$
$$=\frac{1}{2}\left\{\frac{1}{2}\left[F(\omega-2\omega_c)+F(\omega)\right]H_V(\omega-\omega_c)\right\}$$
$$+\frac{1}{2}\left\{\frac{1}{2}\left[F(\omega)+F(\omega+2\omega_c)\right]H_V(\omega+\omega_c)\right\}$$
$$=\frac{1}{4}F(\omega)\left[H_V(\omega-\omega_c)+H_V(\omega+\omega_c)\right]$$
$$+\frac{1}{4}\left[F(\omega-2\omega_c)H_V(\omega-\omega_c)+F(\omega+2\omega_c)H_V(\omega+\omega_c)\right]$$

VSB的相干解调

经过LPF

$$S_d(\omega)=\frac{1}{4}F(\omega)\left[H_V(\omega-\omega_c)+H_V(\omega+\omega_c)\right]$$



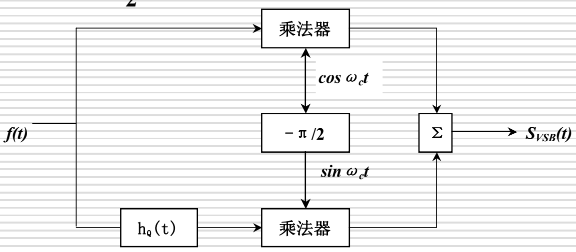
VSB的相干解调

- 若要不产生失真，需在频带$|\omega|<\omega_m$内 $H_V(\omega-\omega_c)+H_V(\omega+\omega_c)$=常数
- 设此常数=2

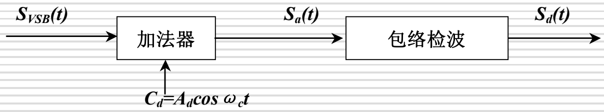
$$S_d(\omega)=\frac{1}{2}F(\omega)$$
$$S_d(t)=\frac{1}{2}f(t)$$

插入强载波的包络检波

$$H_I(\omega)=\frac{1}{2}\left[H_V(\omega-\omega_c)+H_V(\omega+\omega_c)\right]=1$$



插入强载波的包络检波



$$S_I(t)=h_I(t)*f(t)$$

$$S_Q(t)=h_Q(t)*f(t)$$

$$S(t)=S_I(t)\cos\omega_c t+S_Q(t)\sin\omega_c t$$

$$S_a(t)=S_{VSB}(t)+C_d(t)=\left[S_I(t)+A_d\right]\cos\omega_c t+S_Q(t)\sin\omega_c t$$

$$=A(t)\cos\left[\omega_c t+\varphi_c(t)\right]$$

插入强载波的包络检波

- 瞬时幅度 $A(t)=\sqrt{A_d^2+S_I^2(t)+2A_dS_I(t)+S_Q^2(t)}$
- 瞬时相位 $\varphi_c(t)=arctg\left\{S_Q(t)/\left[A_d+S_I(t)\right]\right\}$
- 若载波幅度A_d很大

  $$A(t)\approx\left\{\left[A_d+S_I(t)\right]^2\right\}^{1/2}\approx A_d+S_I(t)$$
- 包络检波后

  $$S_d(t)=S_I(t)\propto f(t)$$