EEEN 322 PS 4 QUESTIONS

Q1

4.3-2 Sketch the AM signal $[A+m(t)]\cos\omega_c t$ for the periodic triangle signal $m(t)$ shown in Fig. P4.3-2 corresponding to the modulation index: **(a)** $\mu = 0.5$; **(b)** $\mu = 1$; **(c)** $\mu = 2$; **(d)** $\mu = \infty$. How do you interpret the case $\mu = \infty$?

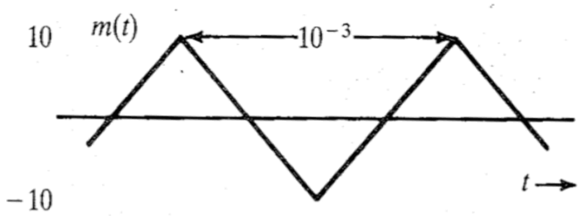

Figure P4.3-2

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Q2

4.3-3 For the AM signal in Prob. 4.3-2 with $\mu = 0.8$:

(a) Find the amplitude and power of the carrier.

(b) Find the sideband power and the power efficiency η.

* *

Q3

4.5-1 A modulating signal $m(t)$ is given by:

(a) $m(t) = \cos 100t$

(b) $m(t) = \cos 100t + 2\cos 300t$

(c) $m(t) = \cos 100t \cos 500t$

In each case:

(i) Sketch the spectrum of $m(t)$.

(ii) Find and sketch the spectrum of the DSB-SC signal $2m(t)\cos 1000t$.

(iii) From the spectrum obtained in **(ii)**, suppress the LSB spectrum to obtain the USB spectrum.

(iv) Knowing the USB spectrum in **(ii)**, write the expression $\varphi_{USB}(t)$ for the USB signal.

(v) Repeat **(iii)** and **(iv)** to obtain the LSB signal $\varphi_{LSB}(t)$.

* *

Q4

4.5-2 For the signals in Prob. 4.5-1, determine $\varphi_{LSB}(t)$ and $\varphi_{USB}(t)$ using Eq. (4.17) if the carrier frequency $\omega_c = 1000$. *Hint*: If $m(t)$ is a sinusoid, its Hilbert transform $m_h(t)$ is the sinusoid $m(t)$ phase-delayed by $\pi/2$ rad.

$$\varphi_{USB}(t) = m(t)\cos\omega_c t - m_h(t)\sin\omega_c t \quad (4.17a)$$

$$\varphi_{LSB}(t) = m(t)\cos\omega_c t + m_h(t)\sin\omega_c t \quad (4.17b)$$

$$\varphi_{SSB}(t) = m(t)\cos\omega_c t \mp m_h(t)\sin\omega_c t \qquad (4.17c)$$

* *

Q5

4.5-6 An USB signal is generated by using the phase-shift method (Fig. 4.20). If the input to this system is $m_h(t)$ instead of $m(t)$, what will be the output? Is this signal still an SSB signal with bandwidth equal to that of $m(t)$? Can this signal be demodulated [to get back $m(t)$]? If so, how?

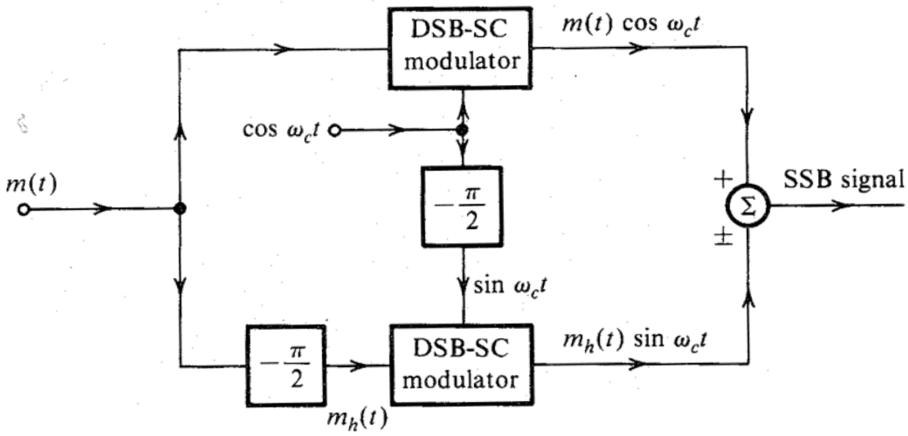

Figure 4.20 SSB generation by phase-shift method.

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EEEN 322 PS 4 SOLUTIONS

Q1

4.3-2

(a) $\mu = 0.5 = \dfrac{m_p}{A} = \dfrac{10}{A} \quad \Rightarrow A = 20$

(b) $\mu = 1.0 = \dfrac{m_p}{A} = \dfrac{10}{A} \quad \Rightarrow A = 10$

(c) $\mu = 2.0 = \dfrac{m_p}{A} = \dfrac{10}{A} \quad \Rightarrow A = 5$

(d) $\mu = \infty = \dfrac{m_p}{A} = \dfrac{10}{A} \quad \Rightarrow A = 0$

This means that $\mu = \infty$ represents the DSB-SC case. Figure S4.3-2 shows various waveforms.

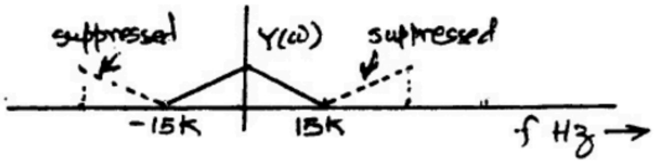

Fig. S4.2-9

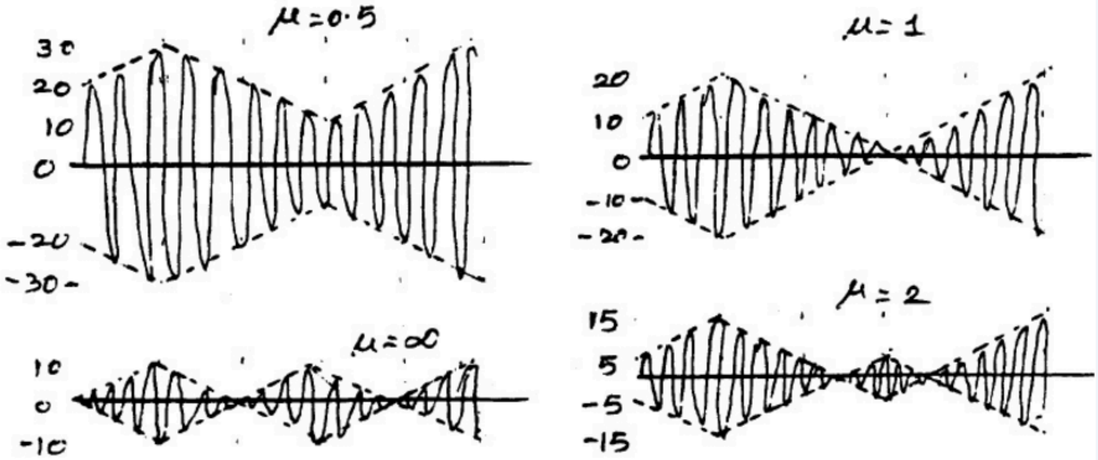

Fig. S4.3-2

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Q2

4.3-3 (a) According to Eq. (4.10a), the carrier amplitude is $A = m_p/\mu = 10/0.8 = 12.8$. The carrier power is $P_c = A^2/2 = 78.125$.

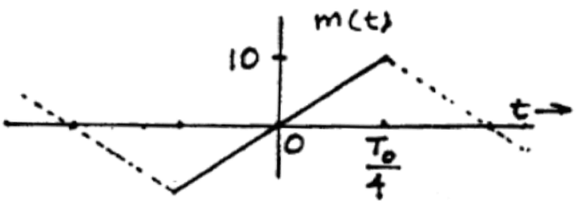


Fig. S4.3-3

(b) The sideband power is $\widetilde{m^2(t)}/2$. Because of symmetry of amplitude values every quarter cycle, the power of $m(t)$ may be computed by averaging the signal energy over a quarter cycle only. Over a quarter cycle $m(t)$ can be represented as $m(t) = 40t/T_0$ (see Fig. S4.3-3). Hence.

$$\widetilde{m^2(t)} = \frac{1}{T_0/4}\int_0^{T_0/4}\left[\frac{40t}{T_0}\right]^2 dt = 33.34$$

The sideband power is

$$P_s = \frac{\widetilde{m^2(t)}}{2} = 16.67$$

The efficiency is

$$\eta = \frac{P_s}{P_c + P_s} = \frac{16.67}{78.125 + 16.67} \times 100 = 19.66\%$$

* *

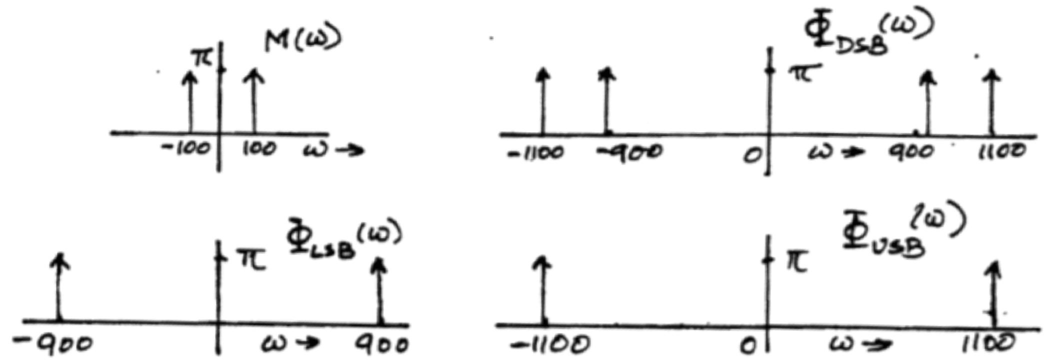
Q3

4.5-1 To generate a DSB-SC signal from $m(t)$, we multiply $m(t)$ with $\cos\omega_c t$. However, to generate the SSB signals of the same relative magnitude, it is convenient to multiply $m(t)$ with $2\cos\omega_c t$. This also avoids the nuisance of the fractions 1/2, and yields the DSB-SC spectrum $M(\omega - \omega_c) + M(\omega + \omega_c)$. We suppress the USB spectrum (above ω_c and below $-\omega_c$) to obtain the LSB spectrum. Similarly, to obtain the USB spectrum, we suppress the LSB spectrum (between $-\omega_c$ and ω_c) from the DSB-SC spectrum. Figures S4.5-1 a, b and c show the three cases.

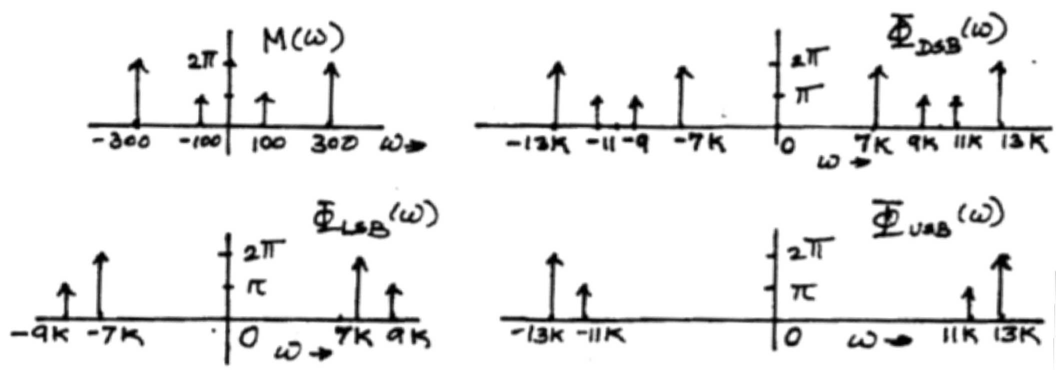
(a)From Fig. a, we can express $\varphi_{LSB}(t) = \cos 900t$ and $\varphi_{USB}(t) = \cos 1100t$.

(b)From Fig. b, we can express $\varphi_{LSB}(t) = 2\cos 700t + \cos 900t$ and $\varphi_{USB}(t) = \cos 1100t + 2\cos 1300t$.

(c)From Fig. c, we can express $\varphi_{LSB}(t) = \frac{1}{2}[\cos 400t + \cos 600t]$ and $\varphi_{USB}(t) = \frac{1}{2}[\cos 1400t + \cos 1600t]$



(a)



(b)

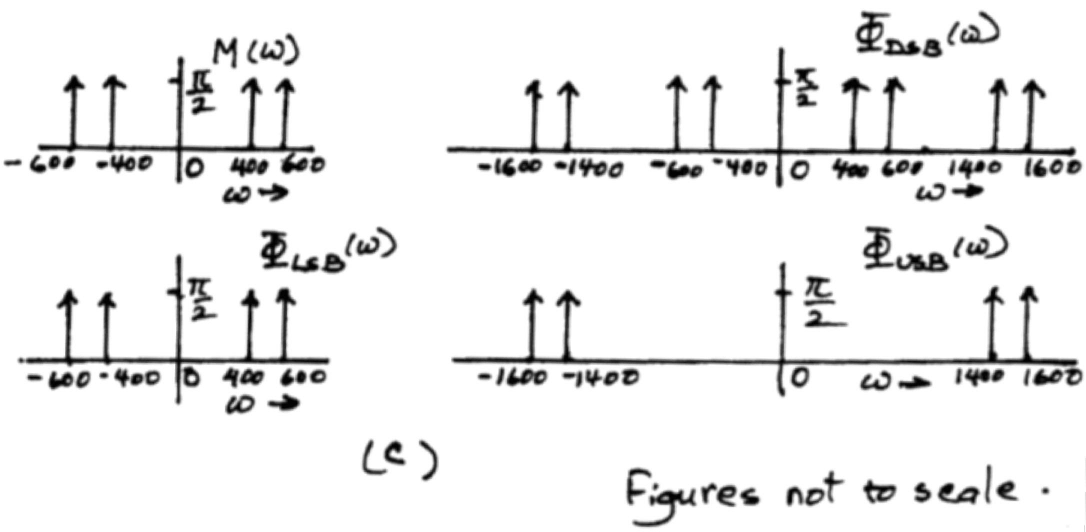


Fig. S4.5-1

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Q4

4.5-2

$$\varphi_{USB}(t) = m(t)\cos\omega_c t - m_h(t)\sin\omega_c t \quad \text{and} \quad \varphi_{LSB}(t) = m(t)\cos\omega_c t + m_h(t)\sin\omega_c t$$

(a) $m(t) = \cos 100t$ and $m_h(t) = \sin 100t$. Hence,

$$\varphi_{LSB}(t) = \cos 100t \cos 1000t + \sin 100t \sin 1000t = \cos(1000-100)t = \cos 900t$$

$$\varphi_{USB}(t) = \cos 100t \cos 1000t - \sin 100t \sin 1000t = \cos(1000+100)t = \cos 1100t$$

(b) $m(t) = \cos 100t + 2\cos 300t$ and $m_h(t) = \sin 100t + 2\sin 300t$. Hence,

$$\varphi_{LSB}(t) = (\cos 100t + 2\cos 300t)\cos 1000t + (\sin 100t + 2\sin 300t)\sin 1000t = \cos 900t + 2\cos 700t$$

$$\varphi_{USB}(t) = (\cos 100t + 2\cos 300t)\cos 1000t - (\sin 100t + 2\sin 300t)\sin 1000t = \cos 1100t + 2\cos 1300t$$

(c) $m(t) = \cos 100t \cos 500t = 0.5\cos 400t + 0.5\cos 600t$ and $m_h(t) = 0.5\sin 400t + 0.5\sin 600t$. Hence.

$$\varphi_{LSB}(t) = (0.5\cos 400t + 0.5\cos 600t)\cos 1000t + (0.5\sin 400t + 0.5\sin 600t)\sin 1000t = 0.5\cos 400t + 0.5\cos 600t$$

$$\varphi_{USB}(t) = (0.5\cos 400t + 0.5\cos 600t)\cos 1000t - (0.5\sin 400t + 0.5\sin 600t)\sin 1000t = 0.5\cos 1400t + 0.5\cos 1600t$$

* *

Q5

4.5-6 We showed in prob. 4.5-4 that the Hilbert transform of $m_h(t)$ is $-m(t)$. Hence, if $m_h(t)$ [instead of $m(t)$] is applied at the input in Fig. 4.20. the USB output is

$$\begin{aligned} y(t) &= m_h(t)\cos\omega_c t - m(t)\sin\omega_c t \\ &= m(t)\cos\left(\omega_c t + \frac{\pi}{2}\right) + m_h(t)\sin\left(\omega_c t + \frac{\pi}{2}\right) \end{aligned}$$

Thus. if we apply $m_h(t)$ at the input of the Fig. 4.20. the USB output is an LSB signal corresponding to $m(t)$. The carrier also acquires a phase shift $\pi/2$. Similarly. we can show that if we apply $m_h(t)$ at the input of the Fig. 4.20. the LSB output would be an USB signal corresponding to $m(t)$ (with a carrier phase shifted by $\pi/2$).

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