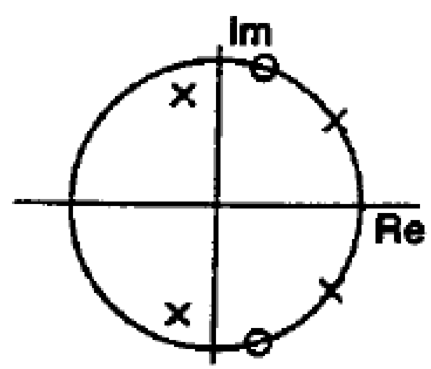
5.35. (a)

$$20\log_{10}|H(e^{j(\pi/5)})| = \infty \Rightarrow \text{pole at } e^{j(\pi/5)}$$

$$20\log_{10}|H(e^{j(2\pi/5)})| = -\infty \Rightarrow \text{zero at } e^{j(2\pi/5)}$$

Resonance at $\omega = \frac{3\pi}{5} \Rightarrow$ pole inside unit circle here.

Since the impulse response is real, the poles and zeros must be in conjugate pairs. The remaining 2 zeros are at zero (the number of poles always equals the number of zeros).



(b) Since $H(z)$ has poles, we know $h[n]$ is IIR.

(c) Since $h[n]$ is causal and IIR, it cannot be symmetric, and thus cannot have linear phase.

(d) Since there is a pole at $|z| = 1$, the ROC does not include the unit circle. This means the system is not stable.

5.38. (a) The causal systems have conjugate zero pairs inside or outside the unit circle. Therefore

$$\begin{aligned}
H(z) &= (1-0.9e^{j0.6\pi}z^{-1})(1-0.9e^{-j0.6\pi}z^{-1})(1-1.25e^{j0.8\pi}z^{-1})(1-1.25e^{-j0.8\pi}z^{-1}) \\
H_1(z) &= (0.9)^2(1.25)^2(1-(10/9)e^{j0.6\pi}z^{-1})(1-(10/9)e^{-j0.6\pi}z^{-1})\cdot \\
&\quad (1-0.8e^{j0.8\pi}z^{-1})(1-0.8e^{-j0.8\pi}z^{-1}) \\
H_2(z) &= (0.9)^2(1-(10/9)e^{j0.6\pi}z^{-1})(1-(10/9)e^{-j0.6\pi}z^{-1})(1-1.25e^{j0.8\pi}z^{-1})\cdot \\
&\quad (1-1.25e^{-j0.8\pi}z^{-1}) \\
H_3(z) &= (1.25)^2(1-0.9e^{j0.6\pi}z^{-1})(1-0.9e^{-j0.6\pi}z^{-1})(1-0.8e^{j0.8\pi}z^{-1})\cdot \\
&\quad (1-0.8e^{-j0.8\pi}z^{-1})
\end{aligned}$$

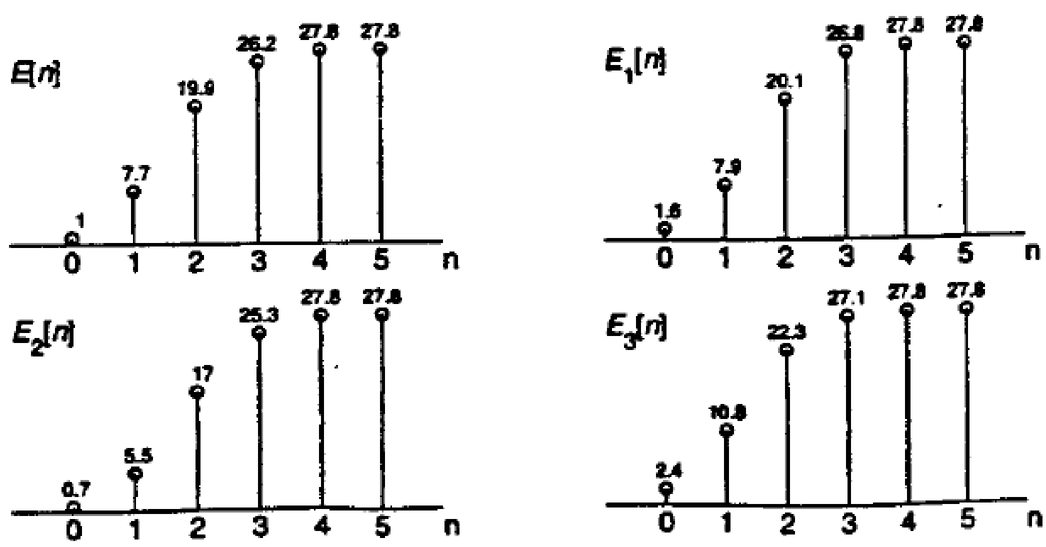
$H_2(z)$ has all its zeros outside the unit circle, and is a maximum phase sequence. $H_3(z)$ has all its zeros inside the unit circle, and thus is a minimum phase sequence.

(b)

$$\begin{aligned}
H(z) &= 1+2.5788z^{-1}+3.4975z^{-2}+2.5074z^{-3}+1.2656z^{-4} \\
h[n] &= \delta[n]+2.5788\delta[n-1]+3.4975\delta[n-2]+2.5074\delta[n-3]+1.2656\delta[n-4] \\
H_1(z) &= 1.2656+2.5074z^{-1}+3.4975z^{-2}+2.5788z^{-3}+z^{-4} \\
h_1[n] &= 1.2656\delta[n]+2.5074\delta[n-1]+3.4975\delta[n-2]+2.5788\delta[n-3]+\delta[n-4] \\
H_2(z) &= 0.81+2.1945z^{-1}+3.3906z^{-2}+2.8917z^{-3}+1.5625z^{-4} \\
h_2[n] &= 0.81\delta[n]+2.1945\delta[n-1]+3.3906\delta[n-2]+2.8917\delta[n-3]+1.5625\delta[n-4] \\
H_3(z) &= 1.5625+2.8917z^{-1}+3.3906z^{-2}+2.1945z^{-3}+0.81z^{-4} \\
h_3[n] &= 1.5625\delta[n]+2.8917\delta[n-1]+3.3906\delta[n-2]+2.1945\delta[n-3]+0.81\delta[n-4]
\end{aligned}$$

(c)

n	$E(n)$	$E_1(n)$	$E_2(n)$	$E_3(n)$
0	1.0	1.6	0.7	2.4
1	7.7	7.9	5.5	10.8
2	19.9	20.1	17.0	22.3
3	26.2	26.8	25.3	27.1
4	27.8	27.8	27.8	27.8
5	27.8	27.8	27.8	27.8



The plot of $E_3[n]$ corresponds to the minimum phase sequence.

5.40.

(i) A zero phase sequence has all its poles and zeros in conjugate reciprocal pairs. Generalized linear phase systems are zero phase systems with additional poles or zeros at $z = 0, \infty, 1$ or -1.

(ii) A stable system's ROC includes the unit circle.

(a) The poles are not in conjugate reciprocal pairs, so this does not have zero or generalized linear phase. $H_i(z)$ has a pole at $z = 0$ and perhaps $z = \infty$. Therefore, the ROC is $0 < |z| < \infty$, which means the inverse is stable. If the ROC includes $z = \infty$, the inverse will also be causal.

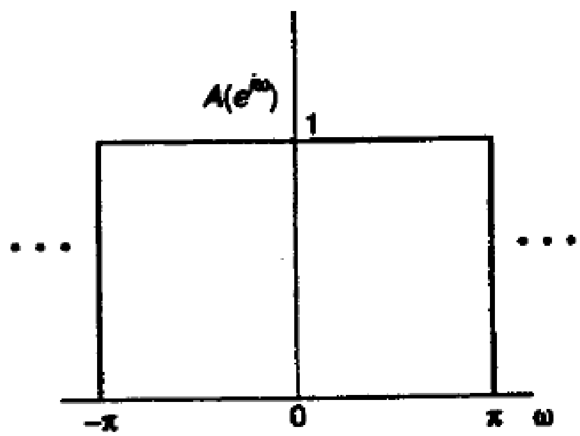
(b) Since the poles are not conjugate reciprocal pairs, this does not have zero or generalized linear phase either. $H_i(z)$ has poles inside the unit circle, so ROC is $|z| > \frac{2}{3}$ to match the ROC of $H(z)$. Therefore, the inverse is both stable and causal.

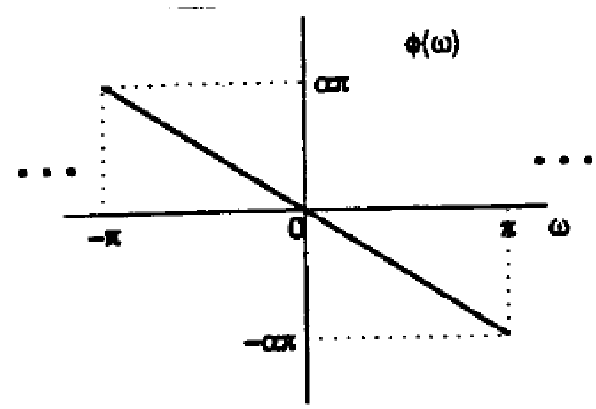
(c) The zeros occur in conjugate reciprocal pairs, so this is a zero phase system. The inverse has poles both inside and outside the unit circle. Therefore, a stable non-causal inverse exists.

(d) The zeros occur in conjugate reciprocal pairs, so this is a zero phase system. Since the poles of the inverse system are on the unit circle a stable inverse does not exist.

5.42. (a)

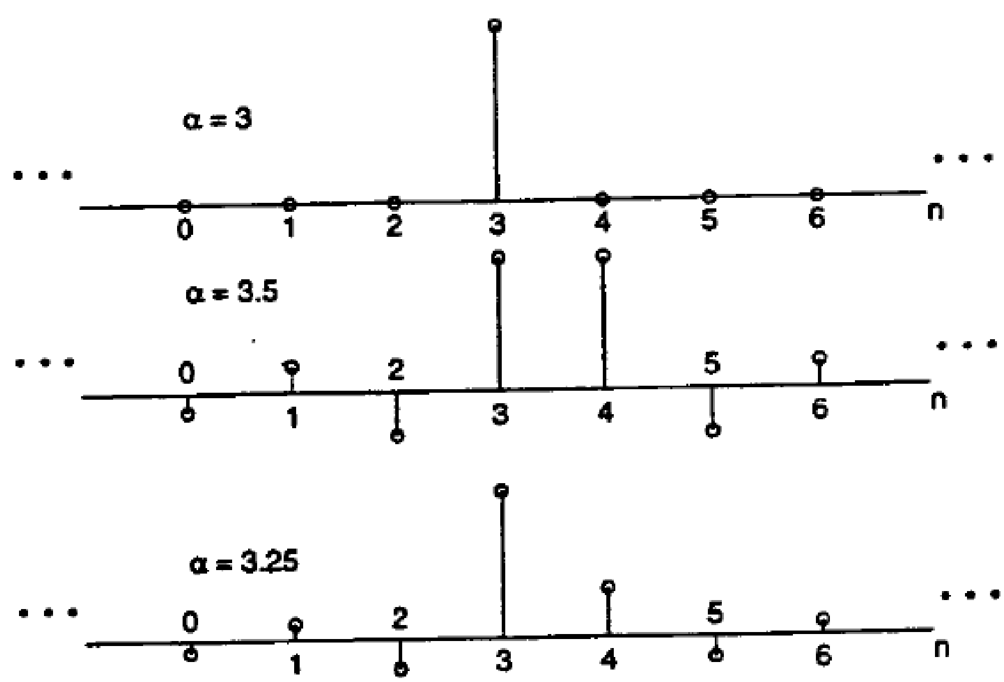
$$A(e^{j\omega}) = 1, \quad |\omega| < \pi$$
$$\phi(\omega) = -\alpha\omega, \quad |\omega| < \pi$$





(b)

$$h[n] = \frac{1}{2\pi}\int_{-\pi}^{\pi} e^{-j\alpha\omega}e^{j\omega n}d\omega = \frac{\sin\pi(n-\alpha)}{\pi(n-\alpha)}$$



(c) If α is an integer, then $h[n]$ is symmetric about about the point $n = \alpha$. If $\alpha = \frac{M}{2}$, where M is odd, then $h[n]$ is symmetric about $\frac{M}{2}$, which is not a point of the sequence. For α in general, $h[n]$ will not be symmetric.

5.57. (a)

$$x[n] = s[n]\cos\omega_0 n = \frac{1}{2}s[n]e^{j\omega_0 n} + \frac{1}{2}s[n]e^{-j\omega_0 n}$$

$$X(e^{j\omega}) = \frac{1}{2}S(e^{j(\omega-\omega_0)}) + \frac{1}{2}S(e^{j(\omega+\omega_0)})$$

$$Y(e^{j\omega}) = H(e^{j\omega})X(e^{j\omega}) = \frac{1}{2}e^{-j\phi_0}S(e^{j(\omega-\omega_0)}) + \frac{1}{2}e^{j\phi_0}S(e^{j(\omega+\omega_0)})$$

$$\begin{aligned} y[n] &= \frac{1}{2}s[n]e^{j(\omega_0 n-\phi_0)} + \frac{1}{2}s[n]e^{-j(\omega_0 n-\phi_0)} \\ &= s[n]\cos(\omega_0 n - \phi_0) \end{aligned}$$

(b) This time,

$$Y(e^{j\omega}) = H(e^{j\omega})X(e^{j\omega}) = \frac{1}{2}e^{-j\phi_0}e^{-j\omega n_d}S(e^{j(\omega-\omega_0)}) + \frac{1}{2}e^{j\phi_0}e^{-j\omega n_d}S(e^{j(\omega+\omega_0)})$$

$$\begin{aligned} y[n] &= \delta[n-n_d] * \left(\frac{1}{2}s[n]e^{j(\omega_0 n-\phi_0)} + \frac{1}{2}s[n]e^{-j(\omega_0 n-\phi_0)}\right) \\ &= \delta[n-n_d] * s[n]\cos(\omega_0 n - \phi_0) \\ &= s[n-n_d]\cos(\omega_0 n - \omega_0 n_d - \phi_0) \end{aligned}$$

Therefore, if $\phi_1 = \phi_0 + \omega_0 n_d$ then

$$y[n] = s[n-n_d]\cos(\omega_0 n - \phi_1)$$

for narrowband $s[n]$.

(c)

$$\begin{aligned} \tau_{gr} &= -\frac{d}{d\omega}arg[H(e^{j\omega})] = -\frac{d}{d\omega}[-\phi_0 - \omega n_d] = n_d \\ \tau_{ph} &= -\frac{1}{\omega}arg[H(e^{j\omega})] = -\frac{1}{\omega}[-\phi_0 - \omega n_d] = \frac{\phi_0}{\omega} - n_d \end{aligned}$$

$$y[n] = s[n - \tau_{gr}(\omega_0)]\cos[\omega_0(n - \tau_{ph}(\omega_0))]$$

(d) The effect would be the same as the following:

(i) Bandlimit interpolate the composite signal to a C–T signal with some rate T.

(ii) Delay the envelope by $T \cdot \tau_{gr}$, and delay the carrier by $T \cdot \tau_{ph}$.

(iii) Sample to a D–T signal at rate T