

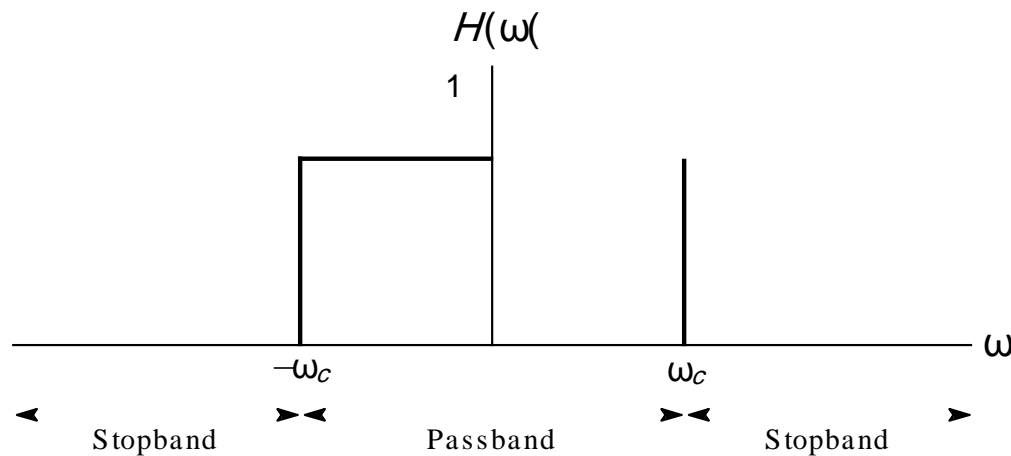
- In many applications, we want to *modify the spectrum* of a signal by either amplifying or attenuating certain frequency components.
- This process of modifying the frequency spectrum of a signal is called **filtering**.
- A system that performs a filtering operation is called a **filter**.
- Many types of filters exist.
- **Frequency selective filters** pass some frequencies with little or no distortion, while significantly attenuating other frequencies.
- Several basic types of frequency-selective filters include: lowpass, highpass, and bandpass.

- An **ideal lowpass filter** eliminates all frequency components with a frequency whose magnitude is greater than some cutoff frequency, while leaving the remaining frequency components unaffected.
- Such a filter has a *frequency response* H of the form

$$H(\omega) = \begin{cases} 1 & \text{for } |\omega| \leq \omega_c \\ 0 & \text{otherwise} \end{cases}$$

where ω_c is the **cutoff frequency**.

- A plot of this frequency response is given below.

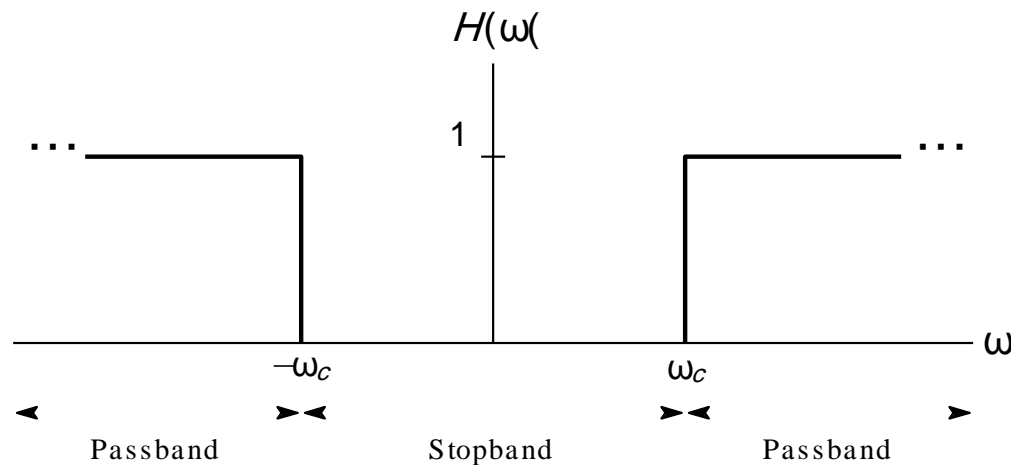


- An **ideal highpass filter** eliminates all frequency components with a frequency whose magnitude is less than some cutoff frequency, while leaving the remaining frequency components unaffected.
- Such a filter has a *frequency response* H of the form

$$H(\omega) = \begin{cases} 1 & \text{for } |\omega| \geq \omega_c \\ 0 & \text{otherwise} \end{cases}$$

where ω_c is the **cutoff frequency**.

- A plot of this frequency response is given below.

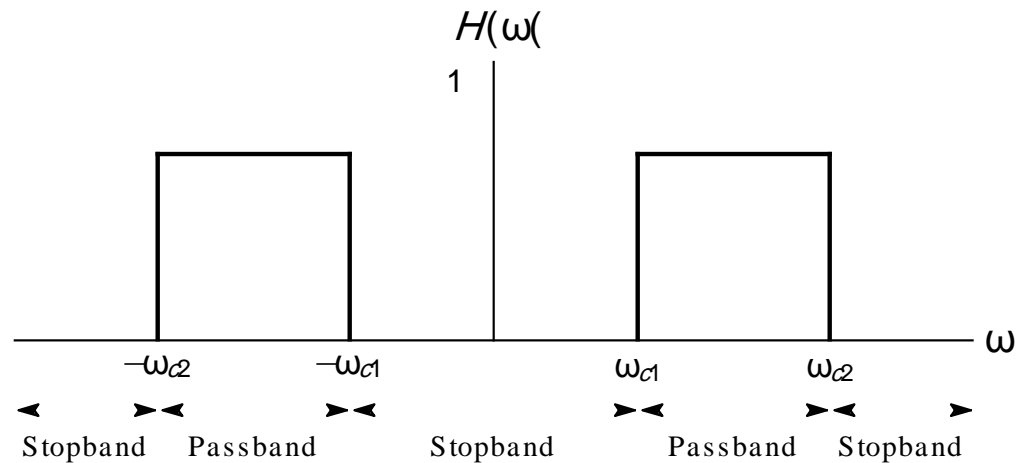


- An **ideal bandpass filter** eliminates all frequency components with a frequency whose magnitude does not lie in a particular range, while leaving the remaining frequency components unaffected.
- Such a filter has a *frequency response* H of the form

$$H(\omega) = \begin{cases} 1 & \text{for } \omega_{c1} \leq |\omega| \leq \omega_{c2} \\ 0 & \text{otherwise} \end{cases}$$

where the limits of the passband are ω_{c1} and ω_{c2} . A

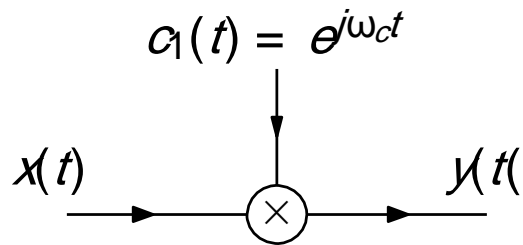
- plot of this frequency response is given below.



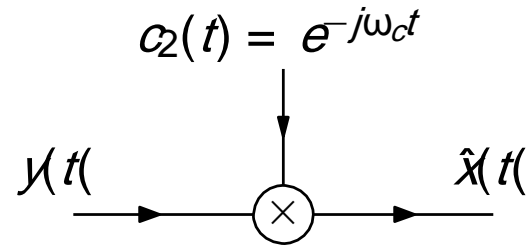
Section 5.8

Application: Amplitude Modulation (AM)

- In communication systems, we often need to transmit a signal using a frequency range that is different from that of the original signal.
- For example, voice/audio signals typically have information in the range of 0 to 22 kHz.
- Often, it is not practical to transmit such a signal using its original frequency range.
- Two potential problems with such an approach are:
 - ① interference; and
 - ② constraints on antenna length.
- Since many signals are broadcast over the airwaves, we need to ensure that no two transmitters use the same frequency bands in order to avoid interference.
- Also, in the case of transmission via electromagnetic waves (e.g., radio waves), the length of antenna required becomes impractically large for the transmission of relatively low frequency signals.
- For the preceding reasons, we often need to change the frequency range associated with a signal before transmission.



Transmitter



Receiver

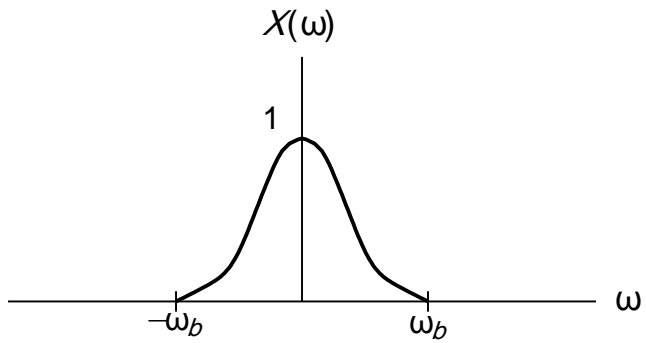
- The transmitter is characterized by

$$y(t) = e^{j\omega_c t} x(t) \quad \Rightarrow \Leftrightarrow \quad Y(\omega) = X(\omega - \omega_c)$$

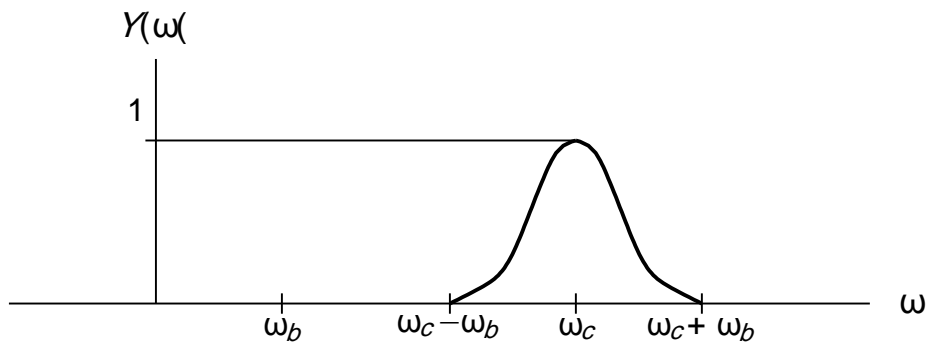
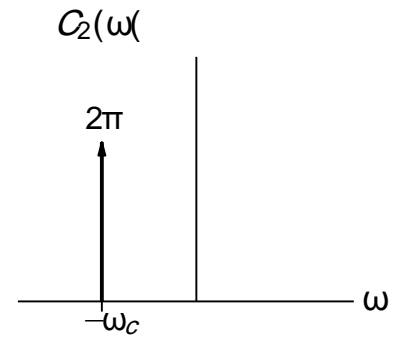
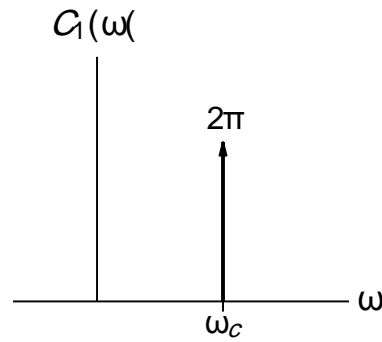
- The receiver is characterized by

$$\hat{x}(t) = e^{-j\omega_c t} y(t) \quad \Rightarrow \Leftrightarrow \quad \hat{X}(\omega) = Y(\omega + \omega_c)$$

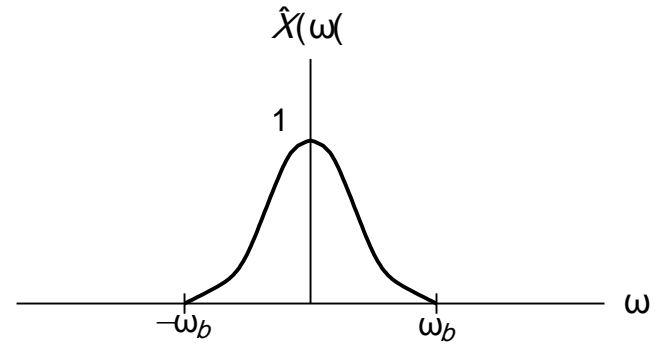
- Clearly, $\hat{x}(t) = e^{j\omega_c t} e^{-j\omega_c t} x(t) = x(t)$.



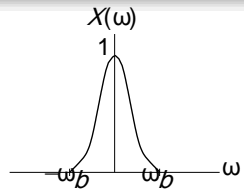
Transmitter Input



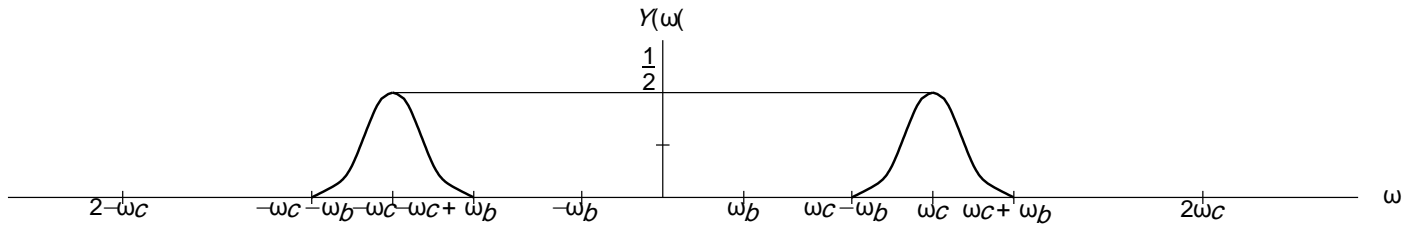
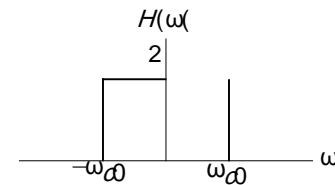
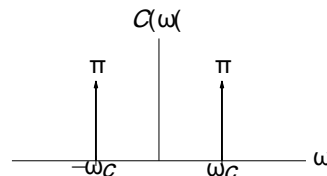
Transmitter Output



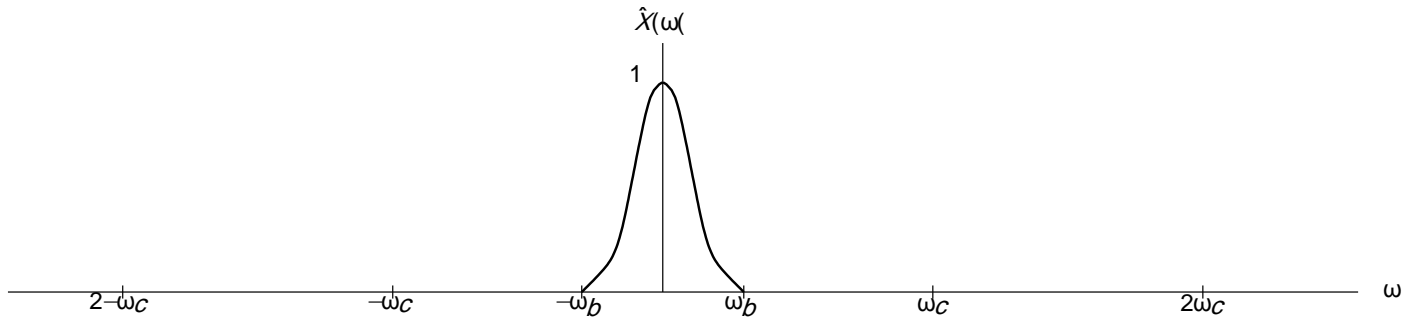
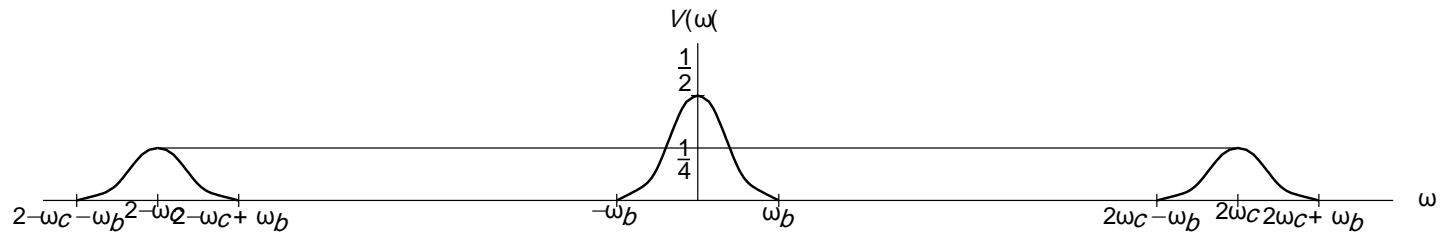
Receiver Output



Transmitter Input

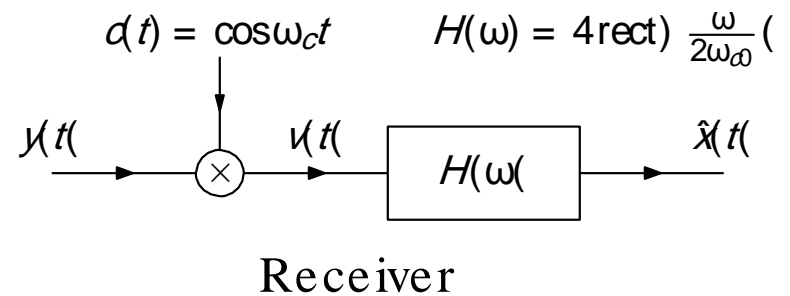
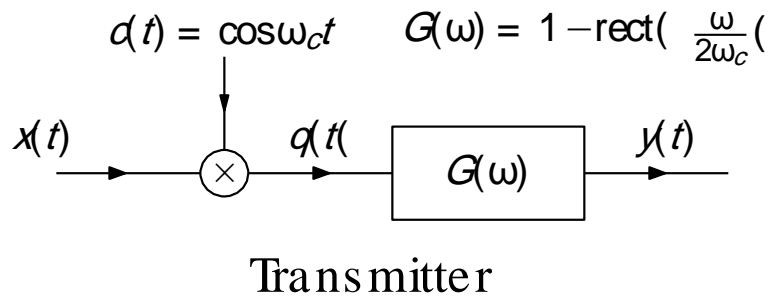


Transmitter Output

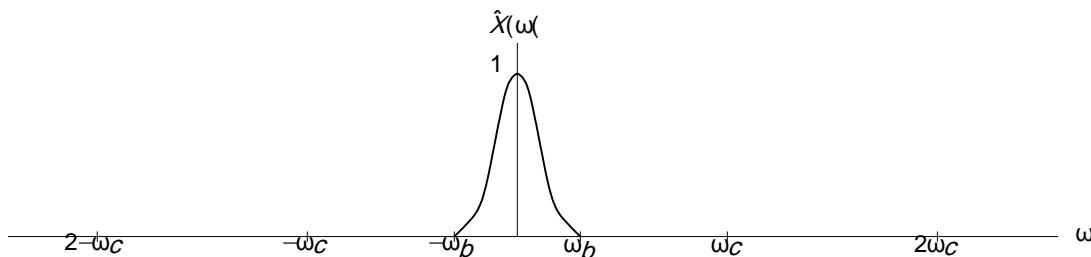
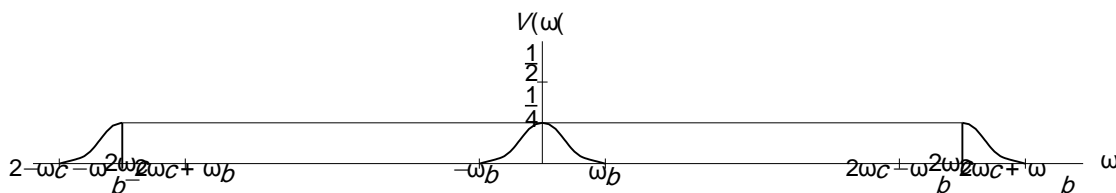
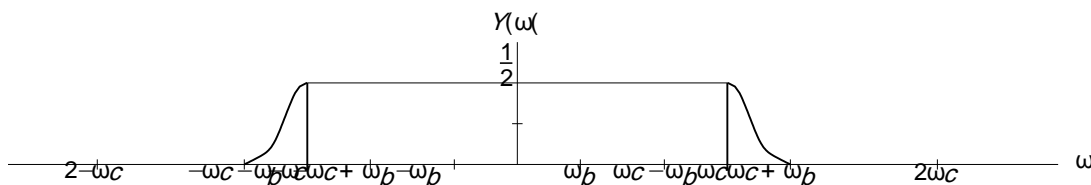
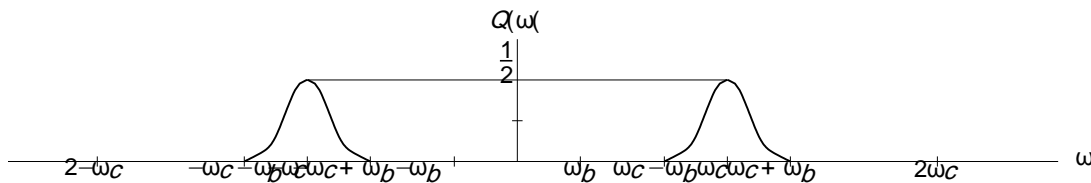
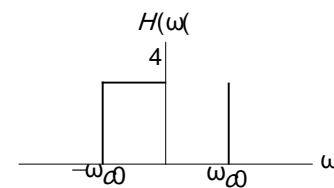
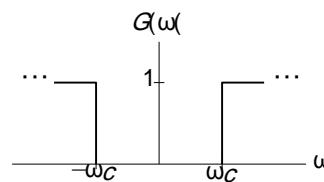
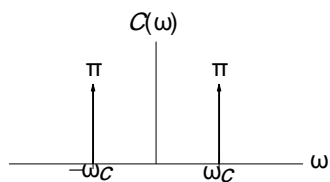
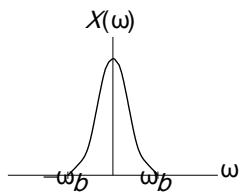


Receiver Output





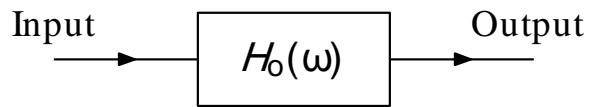
- The basic analysis of the SSB-SC AM system is similar to the DSB-SC AM system.
- SSB-SC AM requires half as much bandwidth for the transmitted signal as DSB-SC AM.



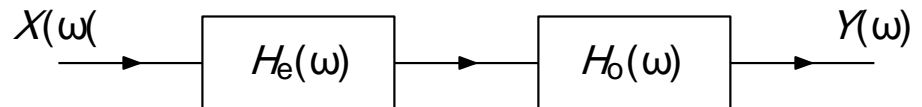
Section 5.9

Application: Equalization

- Often, we find ourselves faced with a situation where we have a system with a particular frequency response that is undesirable for the application at hand.
- As a result, we would like to change the frequency response of the system to be something more desirable.
- This process of modifying the frequency response in this way is referred to as **equalization**. [Essentially, equalization is just a filtering operation.]
- Equalization is used in many applications.
- In real-world *communication systems*, equalization is used to eliminate or minimize the distortion introduced when a signal is sent over a (nonideal) communication channel.
- In *audio applications*, equalization can be employed to emphasize or de-emphasize certain ranges of frequencies. For example, equalization can be used to boost the bass (i.e., emphasize the low frequencies) in the audio output of a stereo.



Original System



New System with Equalization

- Let H_o denote the frequency response of *original* system (i.e., without equalization).
- Let H_d denote the *desired* frequency response.
- Let H_e denote the frequency response of the *equalizer*. The
- new system with equalization has frequency response

$$H_{\text{new}}(\omega) = H_e(\omega) H_o(\omega).$$

- By choosing $H_e(\omega) = H_d(\omega) / H_o(\omega)$, the new system with equalization will have the frequency response

$$H_{\text{new}}(\omega) = [H_d(\omega) / H_o(\omega)] H_o(\omega) = H_d(\omega).$$

- In effect, by using an equalizer, we can obtain a new system with the frequency response that we desire.