ELG3175 Introduction to Communication Systems

Introduction to Amplitude Modulation: DSB-SC

Introduction to modulation

- A message signal, $m(t)$, is to be transmitted.
- Let us assume that this is a baseband signal with bandwidth B_m.
- In other words, $M(f) = 0$ for $|f| > B_m$.
- To transmit the message, we modulate some parameter of a carrier wave as a function of $m(t)$.
- The carrier wave is a sinusoidal signal:

$$c(t) = A_c \cos(2\pi f_c t + \theta_c)$$

- where A_c is the carrier amplitude, f_c is the carrier frequency and θ_c is the carrier phase.
- To simplify expressions, we will assume that $\theta_c = 0$.

Why modulate?

- We use modulation to transmit $m(t)$ for the following reasons:
  - The spectrum of $m(t)$ may fall in a range of frequencies that are not suitable for the channel. By modulating we can move the spectrum of the message signal to a range of frequencies that are appropriate.
  - Antenna lengths are proportional to the wavelength of the signal. Baseband signals require antenna lengths that are not practical. Modulating to a higher frequency reduces the length of the antenna needed to transmit or receive.

Why modulate? (2)

- To separate different signals that are to be transmitted. For example, by using different carrier frequencies, we can multiplex signals so that they can be separated at the receiver. This is called frequency division multiplexing (FDM)

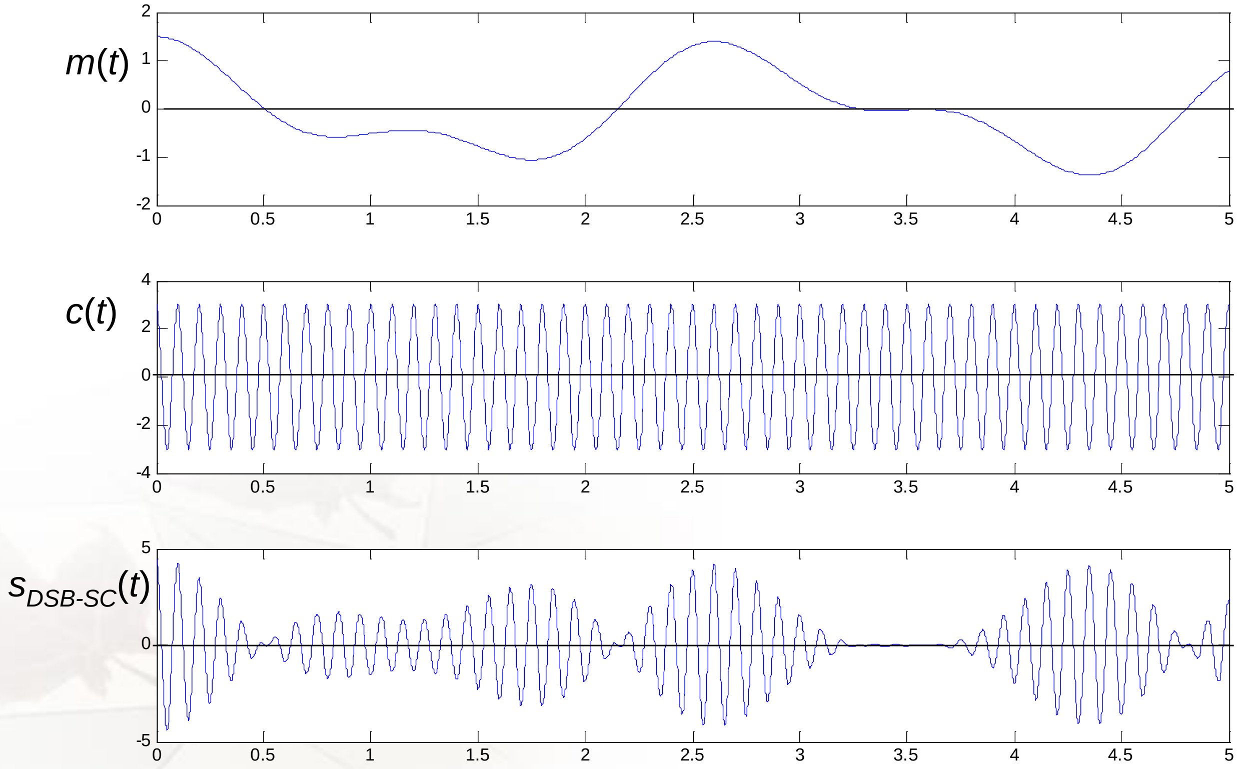
Double Sideband Suppressed Carrier (DSB-SC)

- In amplitude modulation, (AM), the message, $m(t)$ is used to modulate the instantaneous amplitude of the carrier.
- In double sideband suppressed carrier (DSB-SC), only the information bearing modulated carrier is transmitted by multiplying the carrier with the message signal

$$\begin{aligned} s_{DSB-SC}(t) &= m(t)c(t) \\ &= A_c m(t)\cos(2\pi f_c t) \end{aligned}$$

- Where we assume that $f_c >> B_m$.

Example of a DSB-SC signal



Fourier transform of a DSB-SC signal

- The spectrum of a DSB-SC signal is given by:

$$S_{DSB-SC}(f) = \frac{A_c}{2} M(f - f_c) + \frac{A_c}{2} M(f + f_c)$$

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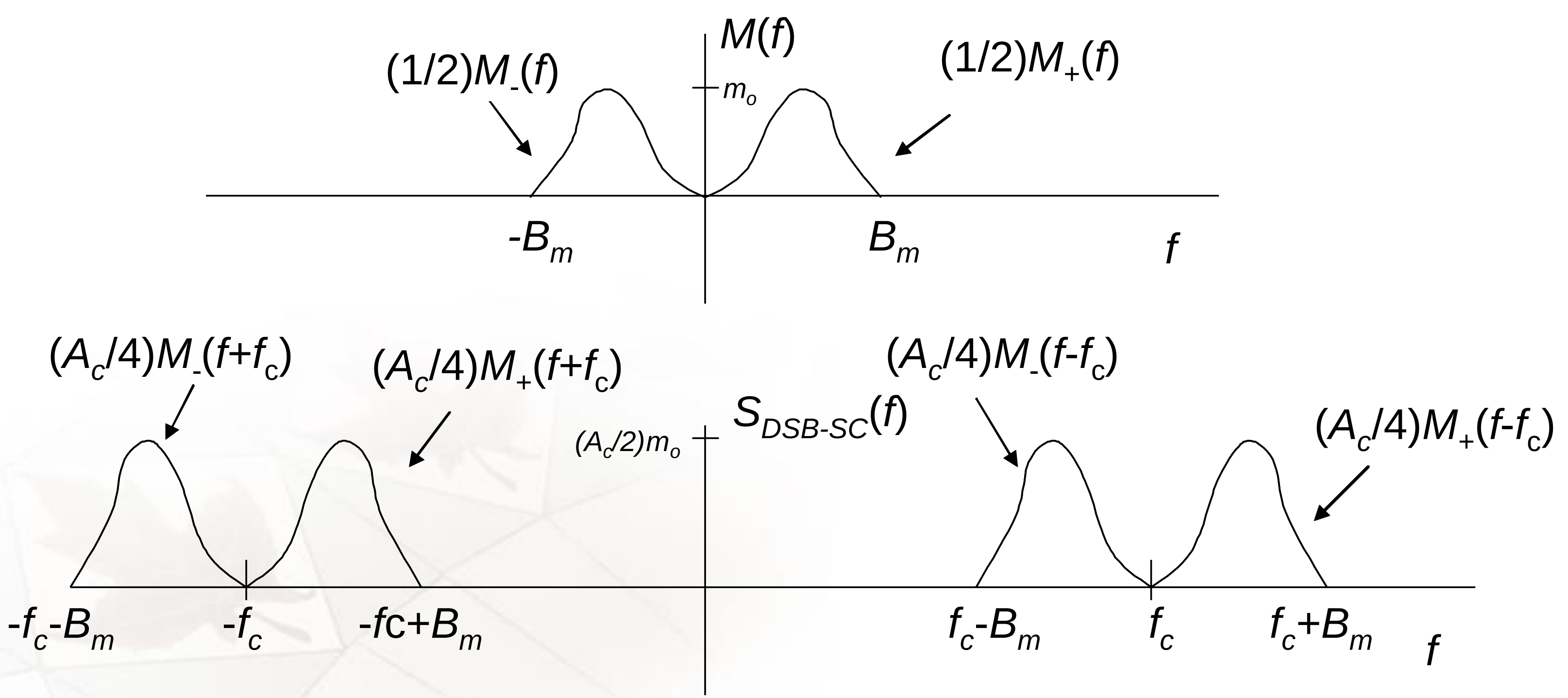
Spectrum of a DSB-SC signal



The two bands

- $M(f) = ½M_+(f) + ½M_-(f)$, therefore $m(t) = ½m_+(t) + ½m_-(t)$.
- In DSB-SC, the upper sideband is the one where $|f| > f_c$. Therefore the spectrum of the upper sideband is $S_{USB}(f) = (A_c/4)M_+(f-f_c) + (A_c/4)M_-(f+f_c)$, which means that $s_{USB}(t) = (A_c/4)m_+(t)e^{j2\pi fct} + (A_c/4)m_-(t)e^{-j2\pi fct}$.
- The lower sideband is the one $|f| < f_c$.
- Therefore its spectrum is $S_{LSB}(f) = (A_c/4)M_-(f-f_c) + (A_c/4)M_+(f+f_c)$.
- Therefore $s_{LSB}(t) = (A_c/4)m_-(t)e^{j2\pi fct} + (A_c/4)m_+(t)e^{-j2\pi fct}$.

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Energy or power of a DSB-SC signal

- We saw that if $m(t)$ is an energy signal with energy E_m, then $A_c m(t)\cos 2\pi f_c t$ is also an energy signal with energy $(A_c^2/2)E_m$.
- Also, if $m(t)$ is a power signal with power P_m, then $A_c m(t)\cos 2\pi f_c t$ is also a power signal with power $(A_c^2/2)P_m$.

Example

- The signal $m(t)$ = sinc(t) is to be transmitted using DSB-SC. The carrier amplitude is 5V and its frequency is 25 Hz.
  - What is the spectrum of the DSB-SC signal?
  - What is the energy of $s_{DSB\text{-}SC}(t)$?

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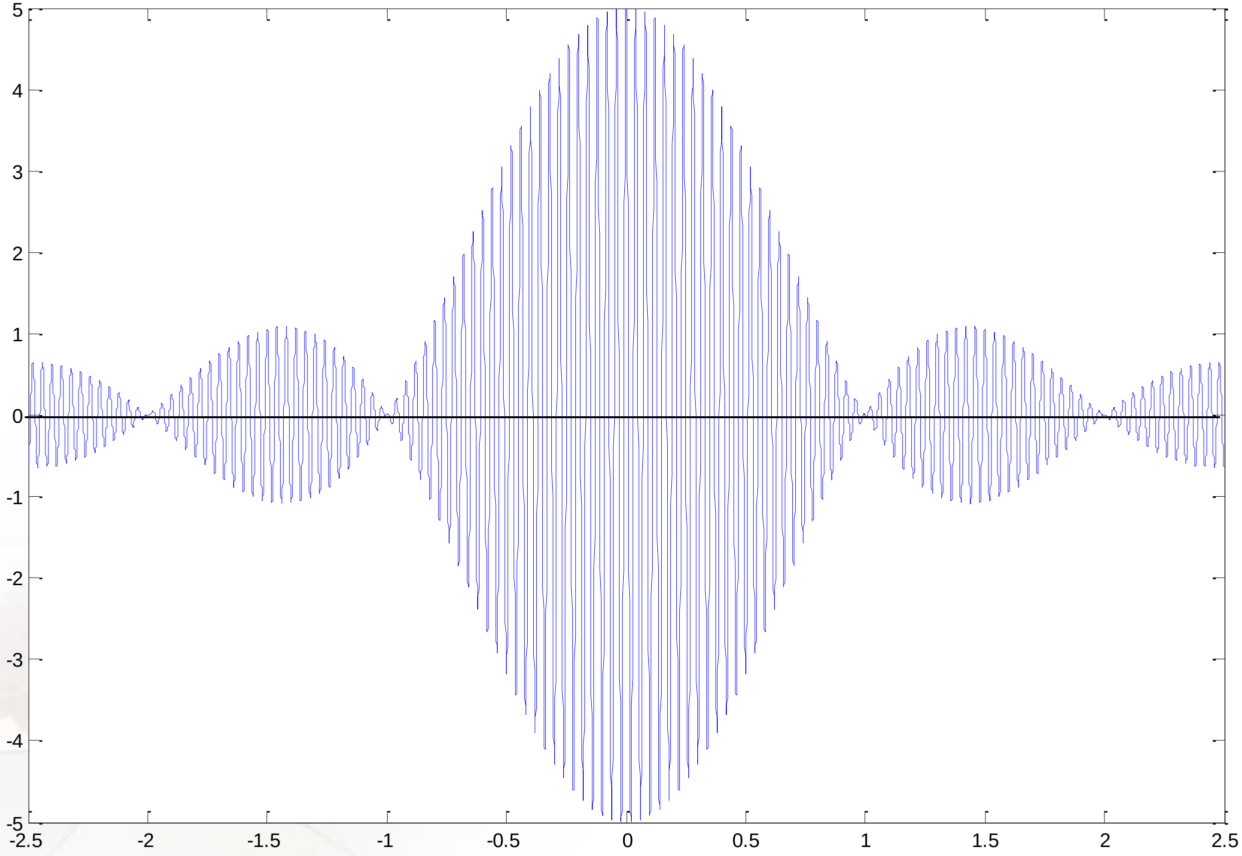
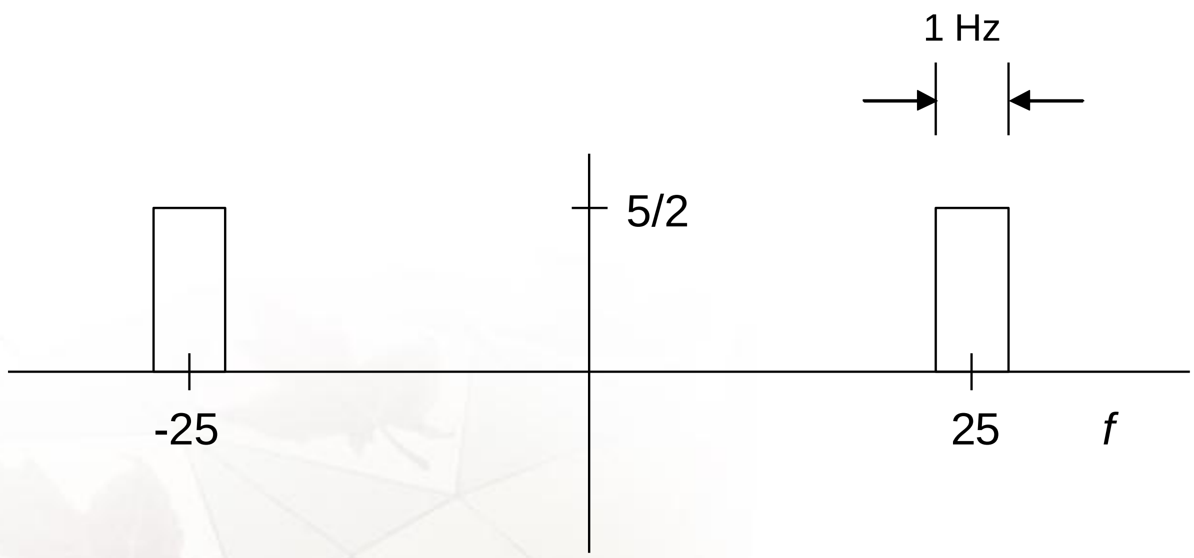
Solution

- The DSB-SC signal is $s_{DSB\text{-}SC}(t) = 5\text{sinc}(t)\cos(2\pi 25t)$.
- Its spectrum is $S_{DSB\text{-}SC}(f) = (5/2)\Pi(f\text{-}25) + (5/2)\Pi(f+25)$.
- The signal sinc(t) is an energy signal with energy E=1, therefore $s_{DSB\text{-}SC}(t)$ is also an energy signal with energy $E = 25/2$.

The DSB-SC signal in our example



The spectrum of the DSB-SC signal in our example



Coherent demodulation of DSB-SC signals

- The receiver must recover $m(t)$ from the received signal.
- If we ignore the effects of transmission (fading, propagation loss, interference, noise etc) then the received signal is $s_{DSB\text{-}SC}(t)$.
- We wish to perform some operation on $s_{DSB\text{-}SC}(t)$ so as to obtain $km(t)$, where k is a constant.
- In coherent detection, we make use of the identity $\cos^2(2\pi f_c t) = ½ + ½ \cos(4\pi f_c t)$.

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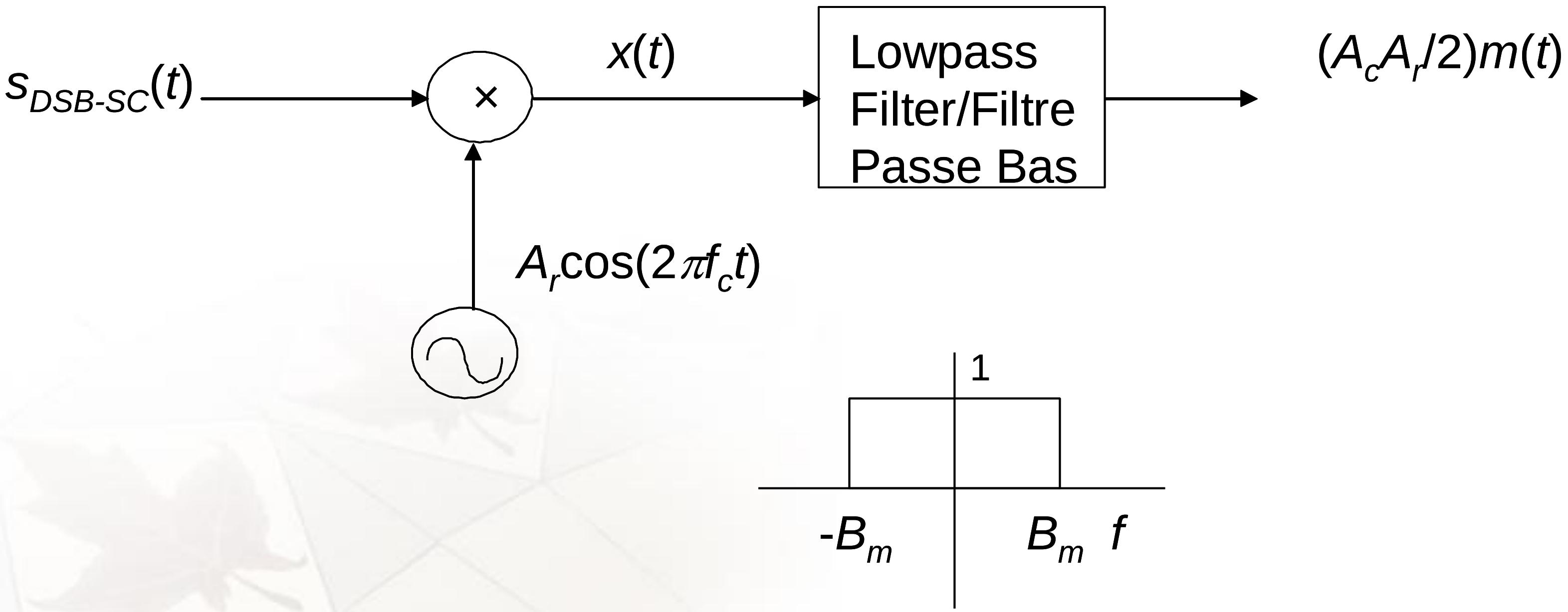
Schema du demodulateur / Block diagram of demodulator



Détection cohérente / Coherent Detection

$$
\begin{aligned}
x(t) &= s_{DSB-SC}(t)c_r(t) \\
&= A_c A_r m(t)\cos^2(2\pi f_c t) \\
&= \underbrace{\frac{A_c A_r}{2} m(t)}_{\substack{\text{baseband signal} \\ \text{passed by the LPF}}} + \underbrace{\frac{A_c A_r}{2} m(t)\cos(4\pi f_c t)}_{\substack{\text{bandpass signal} \\ \text{rejected by LPF}}}
\end{aligned}
$$