ELG3175 Introduction to Communication Systems

Conventional AM

Disadvantages of DSB-SC

- The receiver must generate a replica of the carrier in order to demodulate a DSB-SC signal.
- Any phase and/or frequency error will result in a distorted estimate of the message signal.
- It is difficult to generate a perfect replica of the transmitted carrier.
- A simple modification to the technique results in a less efficient transmission but simplifies the detection process greatly.
- Conventional AM uses noncoherent demodulation.
  - Detection is possible even with frequency and phase errors.

Conventional AM

- Consider a message signal $m(t)$ where $M(f)=0$ for $f=0$,

$$s_{AM}(t) = A_c[1 + k_a m(t)]\cos 2\pi f_c t$$

- where A_c is the carrier amplitude, k_a is the amplitude sensitivity, and f_c is the carrier frequency.
- Also, $f_c >> B_m$ where B_m is the bandwidth of $m(t)$.

Modulation index

- Let us assume that $-m_p \leq m(t) \leq m_p$.
- For conventional AM, $|k_a m(t)| < 1$, or $-1 < k_a m(t) < 1$.
- Therefore, $0 < k_a m_p < 1$, or $0 < k_a < 1/m_p$.
- The modulation index is $\mu_a = k_a m_p$.
- For conventional AM, $0 < \mu_a < 1$.
- Therefore for conventional AM, $[1 + k_a m(t)] > 0$.

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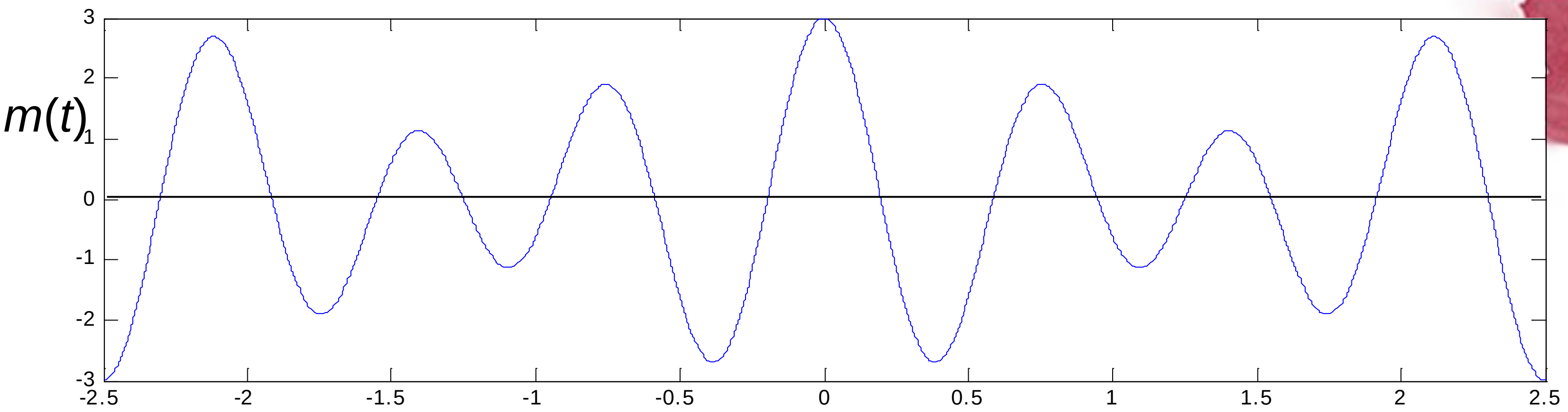
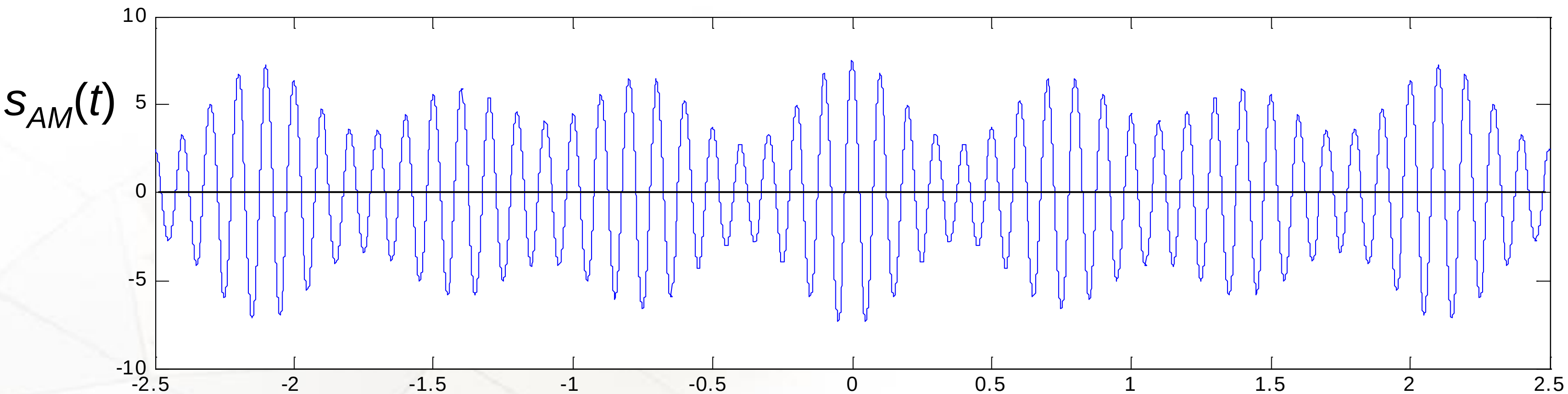
Example 1

- We wish to transmit $m(t) = \cos 2\pi t + 2\cos 2\pi(1.4)t$ using conventional AM. The carrier is $c(t) = 5\cos 2\pi 10t$.
  - Find the value of k_a so that the modulation index is 0.5.
- Solution
- We can show that $-3 \leq m(t) \leq 3$, therefore $m_p = 3$. therefore for $\mu_a = 0.5$, $k_a = 1/6$.
- The resulting AM signal is
  - $s_{AM}(t) = 5[1+(1/6)m(t)]\cos 2\pi 10t$



m(t)
3
2
1
0
-1
-2
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5



s_AM(t)
10
5
0
-5
-10
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

The envelope of an AM signal

- The instantaneous amplitude of $s_{AM}(t)$ is $A_c[1+k_a m(t)]$.
- This instantaneous amplitude is called the signal's envelope.
- The message signal $m(t)$ can be extracted directly from the envelope of $s_{AM}(t)$.

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Overmodulation

- If $\mu_a > 1$, we say that $s_{AM}(t)$ is overmodulated.
- An overmodulated signal cannot be detected using the noncoherent method that is used for conventional AM.
- Take our previous example with $k_a = 0.8$.
- In this case, $\mu_a = k_a m_p = 0.8 \times 3 = 2.4$.
- Therefore, sometimes $k_a m(t) < -1$ leading to $A_c[1+k_a m(t)] < 0$.

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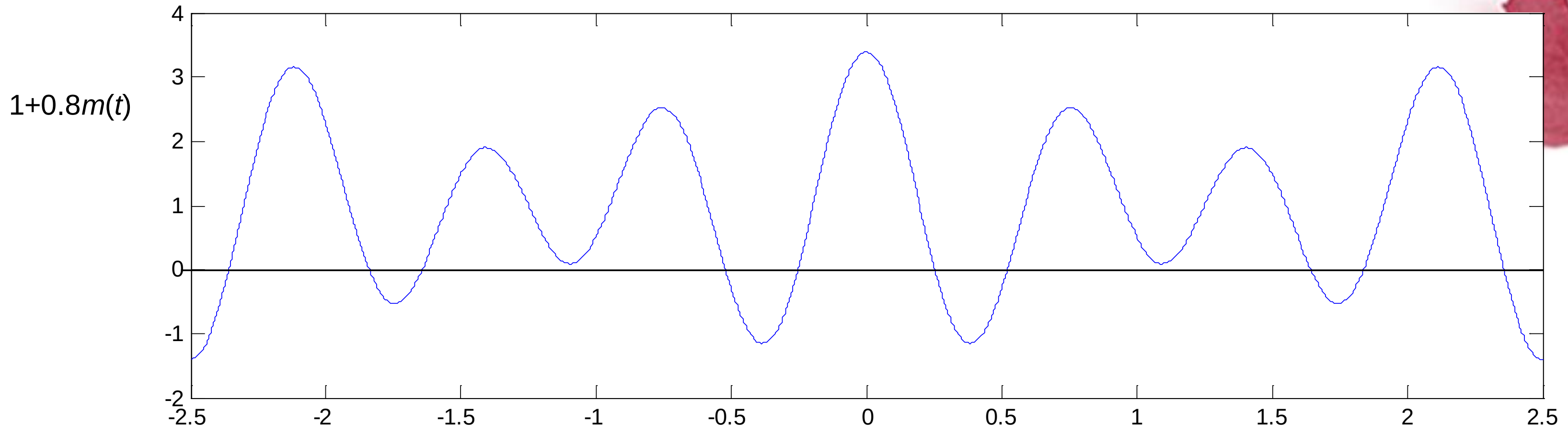
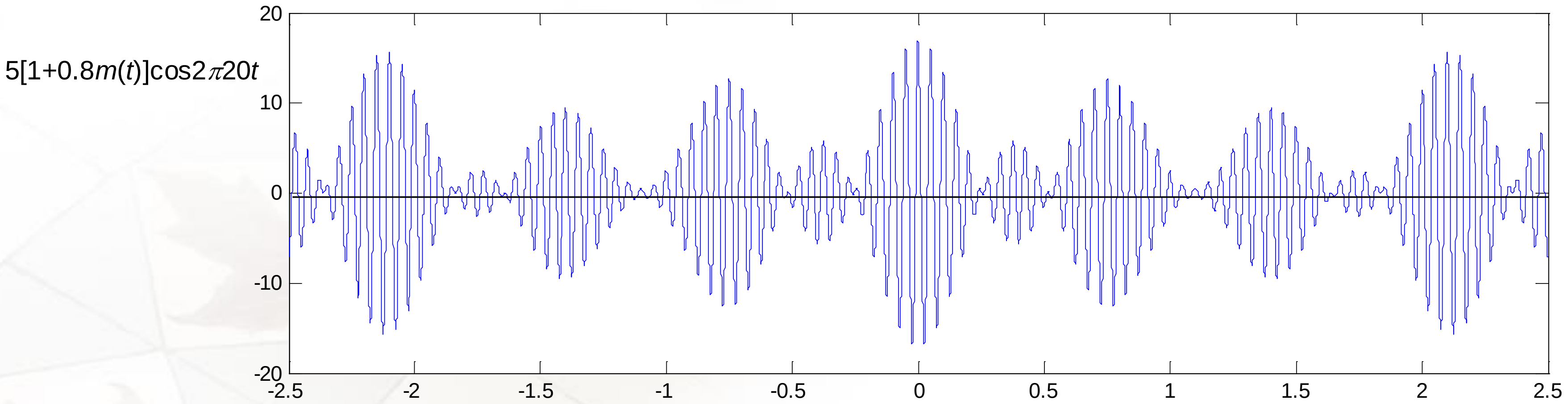

1+0.8m(t)
4
3
2
1
0
-1
-2
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5


5[1+0.8m(t)]cos2π20t
20
10
0
-10
-20
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

Spectrum of Conventional AM signals

- We can express the AM signal as :

$$s_{AM}(t) = A_c \cos 2\pi f_c t + A_c k_a m(t) \cos 2\pi f_c t$$

- Its Fourier transform is $S_{AM}(f) = \mathcal{F}\{s_{AM}(t)\}$ which is given by:

$$S_{AM}(f) = \frac{A_c}{2}\delta(f - f_c) + \frac{A_c}{2}\delta(f + f_c) + \frac{A_c k_a}{2} M(f - f_c) + \frac{A_c k_a}{2} M(f + f_c)$$

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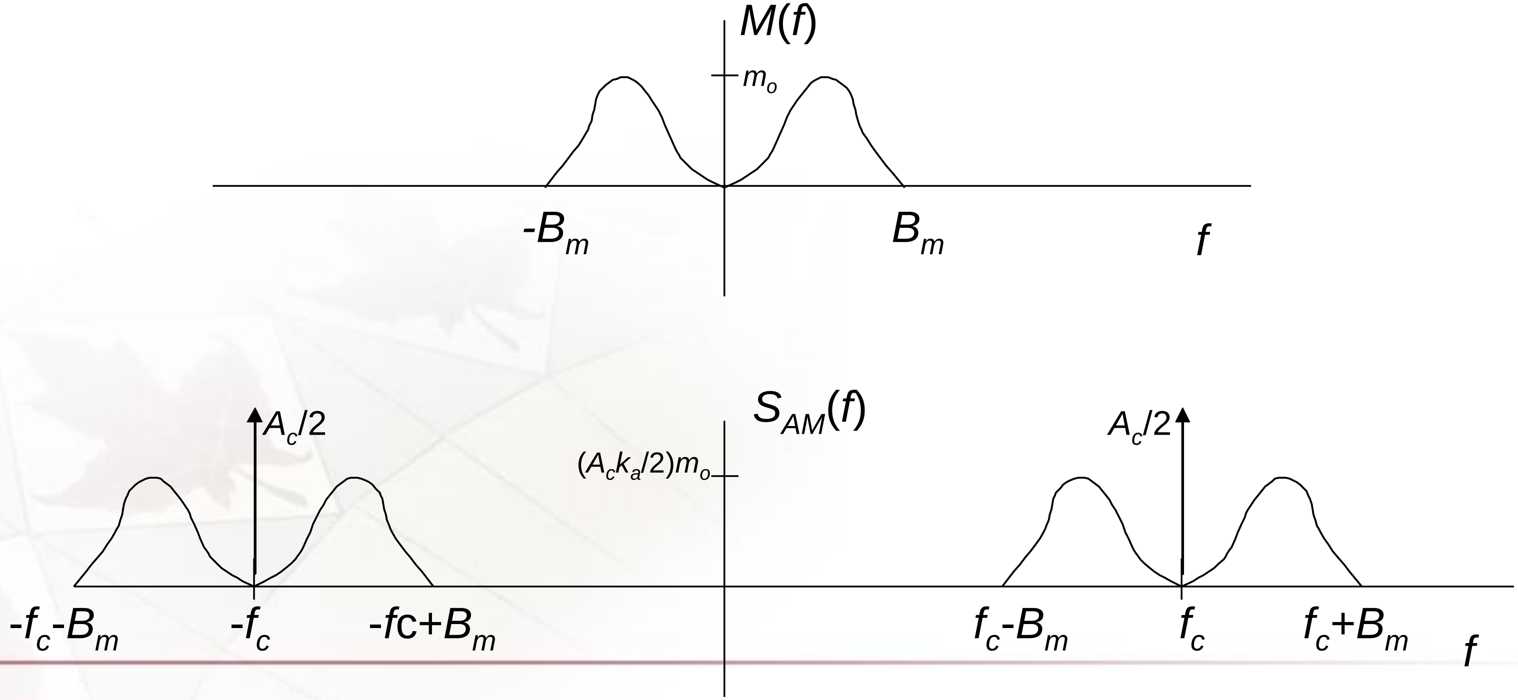
Spectrum of AM signal

- Assuming that $m(t)$ has no DC component, then $M(f\text{-}f_c)$ has no spectral component at $f = f_c$ and $M(f+f_c)$ has no spectral component at $f = -f_c$.



Example 2

- Find the spectrum of $s_{AM}(t) = 5[1+(1/6)m(t)]\cos 2\pi 10t$ where $m(t) = \cos 2\pi t + 2\cos 2\pi(1.4)t$
- SOLUTION
- The signal $m(t)$ has spectrum $M(f) = ½\delta(f-1) + ½\delta(f+1) + \delta(f-1.4) + \delta(f+1.4)$. Therefore the spectrum of $s_{AM}(t)$ is:

$$
\begin{aligned}
S_{AM}(f) &= \frac{5}{2}\delta(f-10) + \frac{5}{2}\delta(f+10) + \frac{5}{12}M(f-10) + \frac{5}{12}M(f+10) \\
&= \frac{5}{2}\delta(f-10) + \frac{5}{2}\delta(f+10) + \frac{5}{24}\delta(f-11) + \frac{5}{24}\delta(f-9) + \frac{5}{12}\delta(f-11.4) \\
&\quad + \frac{5}{12}\delta(f-8.6) + \frac{5}{24}\delta(f+11) + \frac{5}{24}\delta(f+9) + \frac{5}{12}\delta(f+11.4) + \frac{5}{12}\delta(f+8.6)
\end{aligned}
$$

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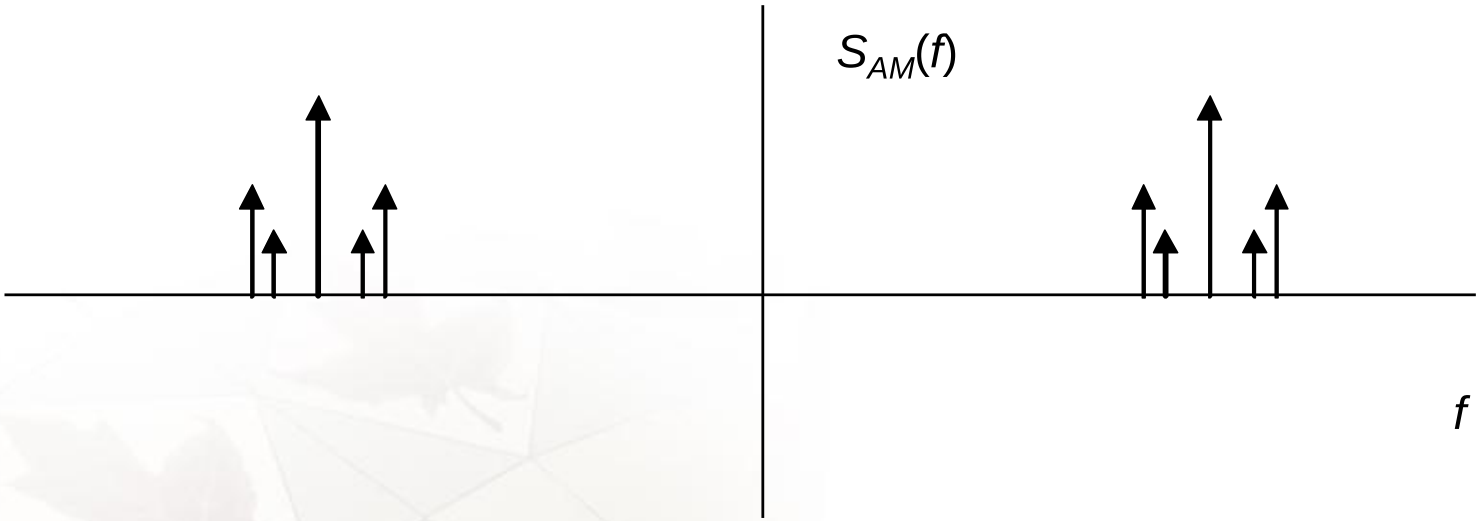

$S_{AM}(f)$
f

Power of a conventional AM signal

- Let's assume that $m(t)$ is a power signal.
- If $m(t)$ has no DC component, then we can find that:

$$P_s = \frac{A_c^2}{2} + \frac{A_c^2 k_a^2 P_m}{2}$$

- where $A_c^2/2$ is the power of the carrier and $A_c^2 k_a^2 P_m/2$ is the power of the component that carries the message.
- The efficiency of a modulation scheme is the ratio of the power dedicated to the transmission of message to the total power of the transmission.
- Therefore the efficiency of conventional AM is:

$$\begin{aligned}\eta &= \frac{A_c^2 k_a^2 P_m}{2} \Bigg/ \left(\frac{A_c^2}{2} + \frac{A_c^2 k_a^2 P_m}{2} \right) \\ &= k_a^2 P_m \Big/ \left(1 + k_a^2 P_m \right)\end{aligned}$$

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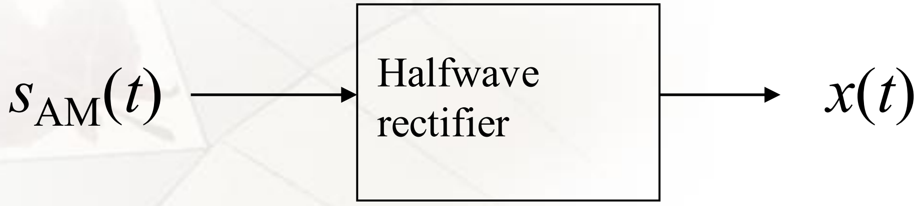
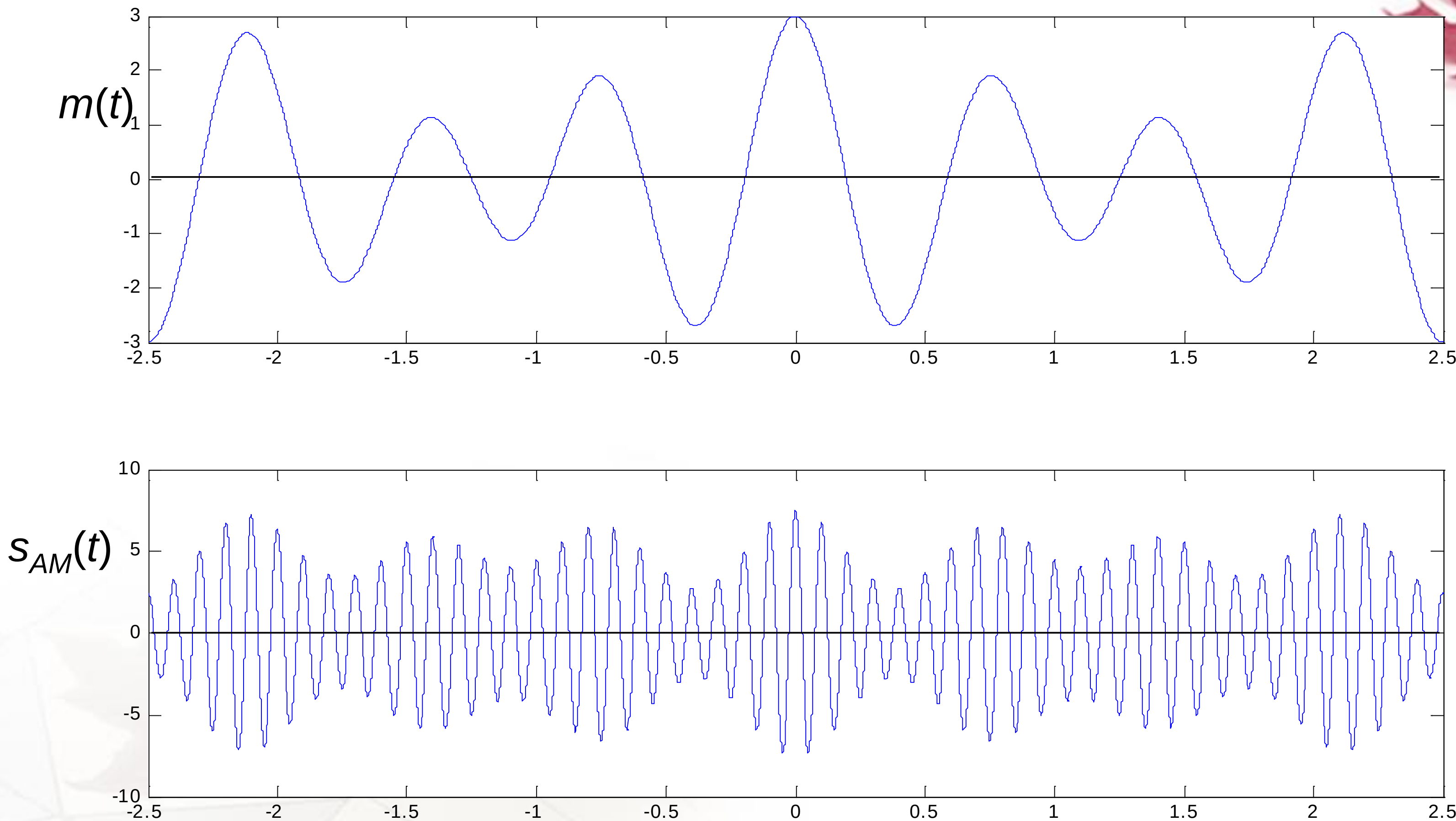
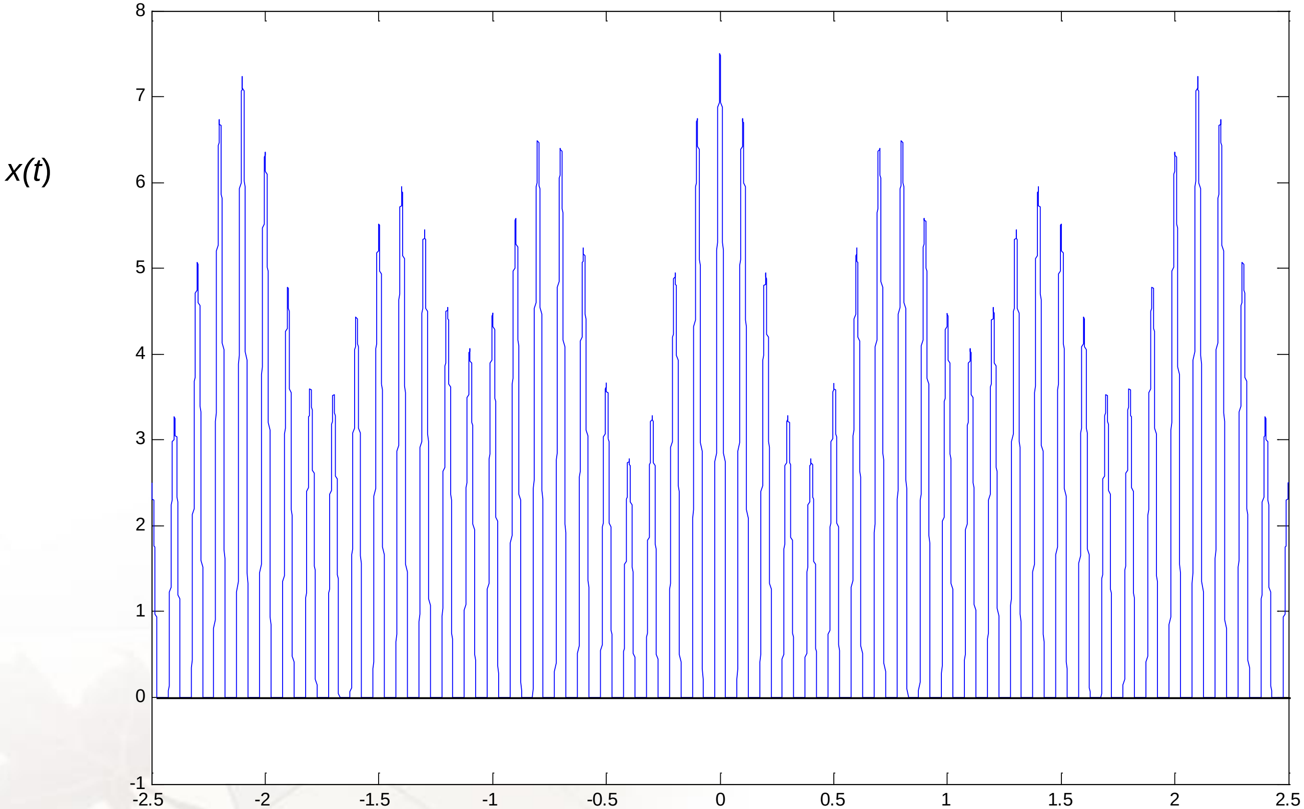
Noncoherent detection

- We know that the envelope of $s_{AM}(t)$ is $A_c[1+k_a m(t)]$.
- An envelope detector is a circuit that outputs the envelope of a bandpass signal.
- A half-wave rectifier with a capacitor filter is a simple envelope detector.
- If $f_c >> B_m$, the output of a halfwave rectifier ressembles a sampled version of the envelope.





m(t)
3
2
1
0
-1
-2
-3
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
s_AM(t)
10
5
0
-5
-10
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5



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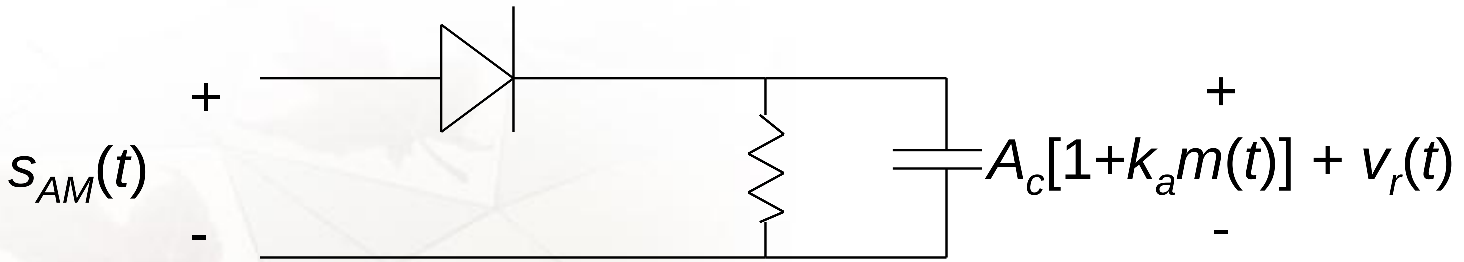
Simple envelope detector

- Applying a low pass filter at the output of the halfwave rectifier should give us a signal that ressembles $A_c[1+k_a m(t)]$.
- Placing a capacitor at the output of the rectifier provides a simple solution.



- The power of $v_r(t)$ is inversely proportional to f_c.

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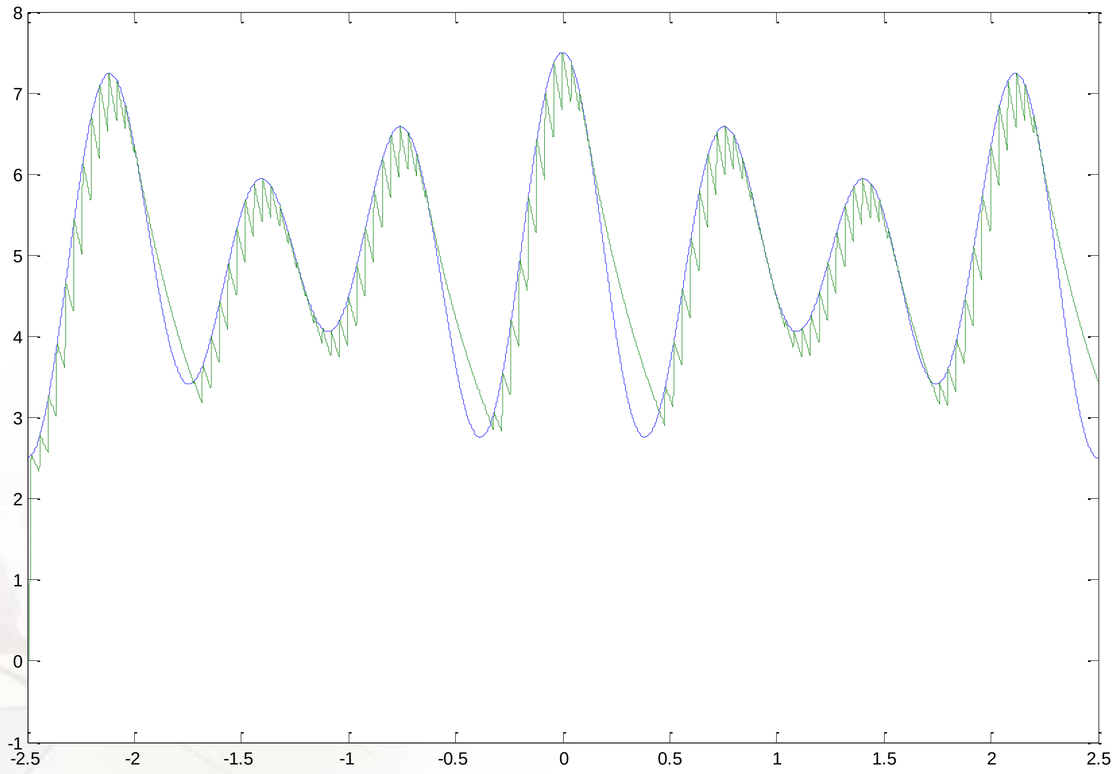
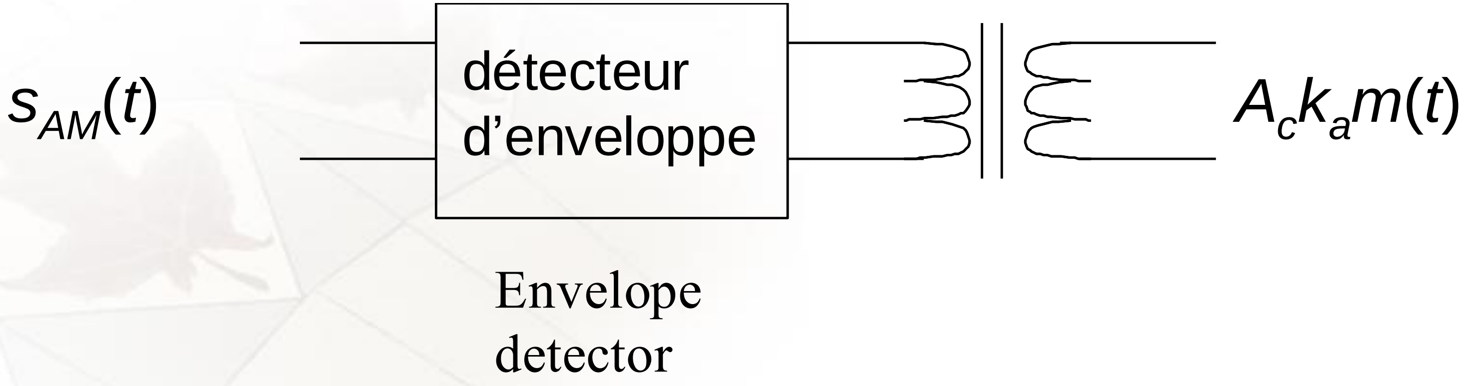
Output of envelope detector compared to actual envelope.



Obtaining $m(t)$ from the envelope

- If we neglect $v_r(t)$, the output of the envelope detector is $A_c + A_c k_a m(t)$.
- Passing this through a device that blocks DC components, such as a transformer, we have $A_c k_a m(t)$ at the output as long as $m(t)$ has no DC component.



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