ETHFE
High Frequency Electronics

AARHUS UNIVERSITY
SCHOOL OF ENGINEERING

Indholdsfortegnelse

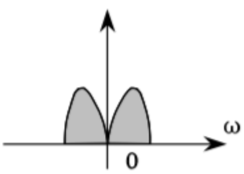
Amplitude modulation

1.1 Lektion 30-01-2018

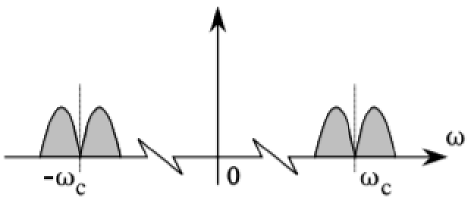
1. Intro
2. AM Modulation/demodulation

- **Pensum:** JV, Ch 1 p 1-6
- **Opgaver:** P.I-1

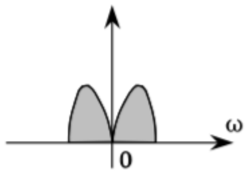
1.1.1 Basic Modulation Types and Concepts



Original baseband signal



Transmitted bandpass signal



Reconstructed baseband signal

- **Modulation:** Hvordan signaler moduleres ind på bærebølger, der efterfølgende typisk sendes ud som elektromagtetiske signaler via et transmissionsmedie.
  - Bandpass signalet er det transmitterede signal til receiveren.
  - Flere baseband signals kan blive transmitteret samtidigt gennem den samme kanal ved forskellige carrier frequencies.

- **Demodulation:** Hvordan det sendte signal demoduleres så det originale signal gendannes.
  - Receiveren gendanner det low-frequency baseband signal.
  - Scopet af demodulationen afhænger af hvilken type data der bliver sendt.
    - *In a radio telephony channel it may suffice at the receiver site to get an output with a power spectrum that contains the dominant part of the input power spectrum.*
    - *In a television video channel it is important to reconstruct in time-domain the shape of the signal being send.*
    - *In digital transmissions, the goal is to rebuild a logical bitstream representation equivalent to the input stream.*

1.1.2 Amplitude Modulations

Typer af moduleringer der er egnet for RF communication kaldes continuous wave modulations, **CW**.

- Baseband information er overlagt en sinusoidal carrier wave med amplitude A_{c0} og vinkelfrekvens ω_c.
  - *Carrier* 1.1
  - *Modulated carrier* 1.2

$$y(t) = A_{c0}\cos(\omega_c t) \tag{1.1}$$

$$y(t) = A(t)\cos(\omega_c t + \phi(t) + \phi_0) \tag{1.2}$$

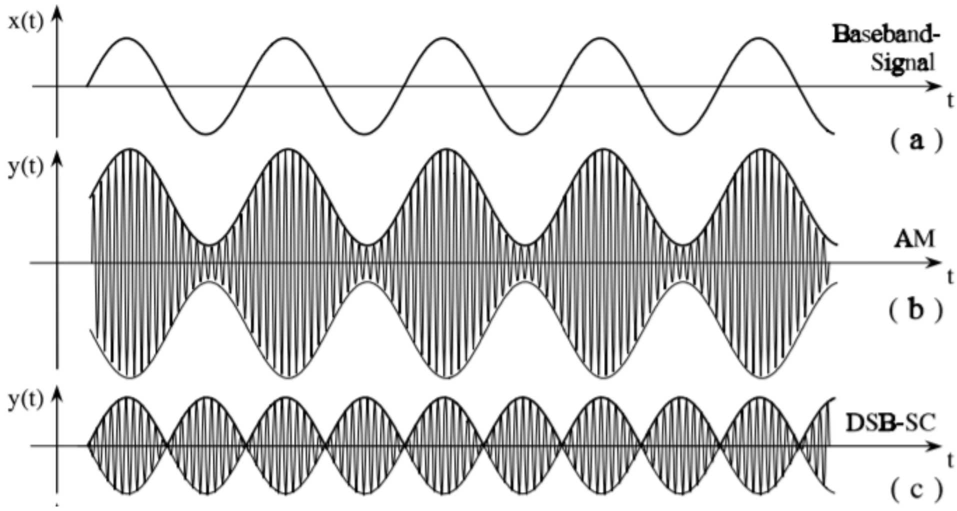
- *The time dependencies of $A(t)$ and $\phi(t)$ in 1.2 contain the baseband message and the angle ϕ_0 represents an offset phase for the carrier compared to the timing of the baseband message.*

- *If there is no synchronism between the two, the offset may be set to zero without loss of generality. Eq. 1.2 is called the envelope-phase representation of a modulated signal.*

Den største forskel mellem forskellige modulation typer er hvordan et baseband signal $x(t)$ indeholder det overlagte signal $y(t)$ som er moduleret. Amplitude modulations indebærer **AM** and **DSB-SC**.

AM

- Skalering af signalniveauerne beregnes ved modulation index m.
- Med et normaliseret baseband signal $|x(t)| \leq 1$, indebærer betingelsen $m \leq 1$ (eller 100%) et undistorted reproduction af baseband signalet.
  - m: modulation index
- Det er let at gendanne baseband signalet fra en AM modulated wave i en receiver med det simple envelope detector circuit.



Figur 1.1: Examples of modulation waveshapes (AM and DSB(-SC)) from a sinusoidal baseband signal $x(t)$.

- Amplitude modulation, $\phi(t) = 0$
  - *amplitude modulation, AM* 1.3
  - *double-sideband (supressed carrier), DSB/DSB-SC* 1.4

$$y(t) = A_{c0}(1 + mx(t))\cos(\omega_c t) \tag{1.3}$$

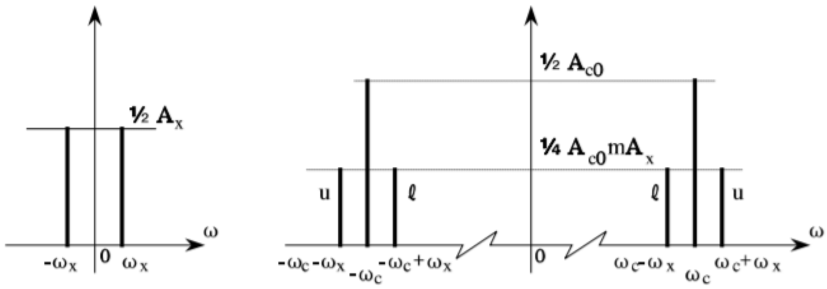
$$y(t) = A_{c0}x(t)\cos(\omega_c t) \tag{1.4}$$

- Envelope detectorens low-pass filter bandwidth skal være højere end envelope frekvensen.

- En AM modulated wave har spektrale komponenter fra baseband signalet over og under carrier signalet.

$$y(t)_{|AM} = A_{c0}(1 + mA_x \cos \omega_x t) \cos \omega_c t \Rrightarrow \tag{1.5}$$

$$A_{c0} \cos \omega_c t + \frac{A_{c0}}{2} mA_x \cos(\omega_c - \omega_x)t + \frac{A_{c0}}{2} mA_x \cos(\omega_c + \omega_x)t \tag{1.6}$$



Figur 1.2: Spectral components in a double-sided amplitude spectrum of the sinusoidal baseband signal and the AM modulated waveform from Eq. 1.6. u and l are the upper and lower sideband components.

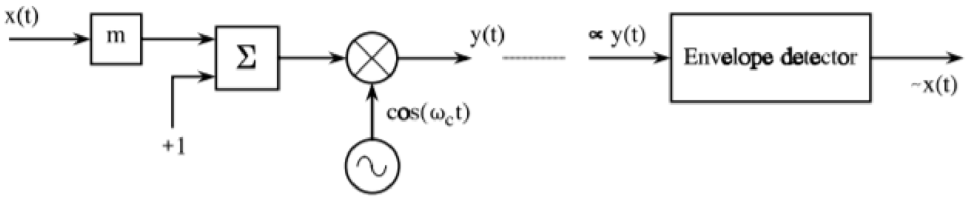
With maximum undistorted modulation, i.e. $m = 1$ and $A_x = 1$, the power of the AM modulated wave, say it is a voltage across a $1\,\Omega$ resistor, becomes;

$$P_{|AM} = \underbrace{2\frac{A_{c0}^2}{4}}_{carrier} + \underbrace{4\frac{A_{c0}^2 m^2 A_x^2}{16}}_{envelope} \tag{1.7}$$

$$P_{|AM} = \frac{1}{2}A_{c0}^2 + \frac{1}{4}A_{c0}^2 \tag{1.8}$$

so at most 33% of the transmitted power contains the message from the baseband signal.

- AM modulated signal i frekvens domænet:
  - Anvender eulers formel ($\cos 2\pi t \to e^{j2\pi\omega_c t} + e^{-j2\pi\omega_c t}$)
  - Fourier transform (gange i tidsdomænet $\cdot$ og folde i frekvenssdomænet $\circledast$)



Figur 1.3: Block schemes for simple AM modulation (left) and demodulation (right).

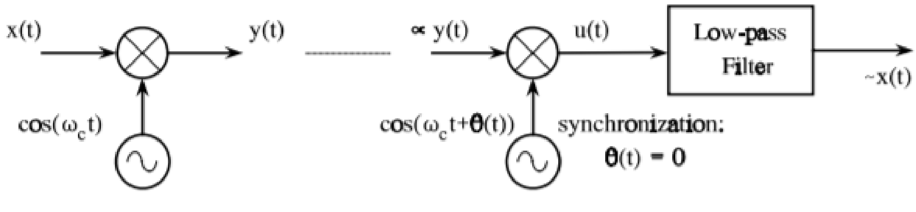
DSB-SC

DSB moduleringen fra Eq. 1.4 har ingen carrier component deraf kommer betegnelsen *suppressed carrier* eller SC.

$$y(t)_{|DSB-SC} = A_{c0}A_x \cos \omega_x t) \cos \omega_c t \tag{1.9}$$

$$y(t)_{|DSB-SC} = \frac{A_{c0}A_x}{2} \cos(\omega_c - \omega_x)t + \frac{A_{c0}A_x}{2} \cos(\omega_c + \omega_x)t \tag{1.10}$$

- Carrier componenterne indeholder ingen information, derfor er det mere kompliceret at gendanne baseband signalet i receiveren.
- For at kunne detektere baseband signalet fra et DSB moduleret signal, skal dette signal igen multipliceres med en carrier.
  - Hvis fasen $\phi(t)$ er forskellig fra nul vil cosine enten reducerer eller forvrænge signalet.
  - For at få et predictable result skal oscillatoren i demodulatoren være synkroniseret med carrier af det modtagede signal.
  - *A simple method is to let a fragment of the full carrier - a pilot carrier - follow the signal.*
    - Gøres ved at indsætte en konstant < 1 istedet for 1.



Figur 1.4: Block schemes for simple DSB-SC modulation (left) and demodulation (right).

Vinkel modulation

2.1 Lektion 06-02-2018

1. Vinkel modulation
2. Phasor repræsentation

- **Pensum:** JV, Ch 1 p 6-13, p 13-18
- **Opgaver:** P.I-2

2.1.1 Vinkel modulation

Vinkel modulation er processen når frekvensen eller phase af carrieren varrierer i forhold til baseband informationen. Her er amplituden A_{c0} konstant. En vigtig fordel ved PM og FM modulation er at de mere imun overfor channel noise, nonlinear distotion og amplitude fading i forhold til AM modulation. Vinkel modulation kræver en dobbelt så stor båndbredde som AM modulation $(2 \cdot W)$.

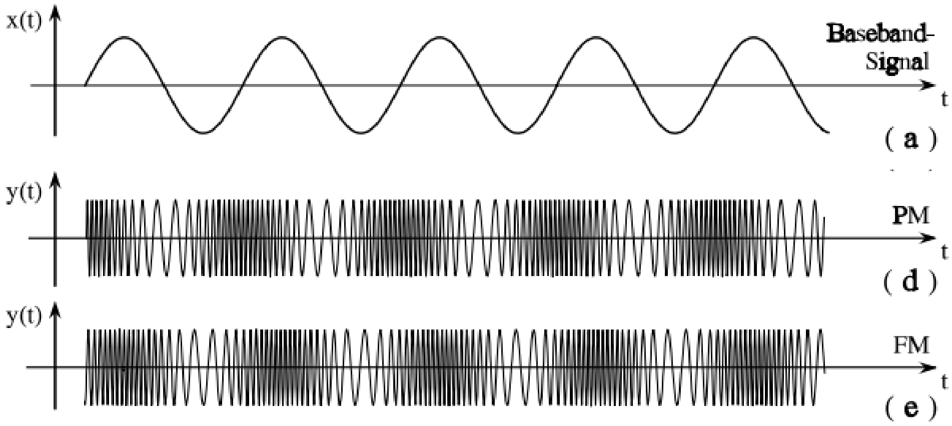
Vinkel modulation er delt op i frekvens (**FM**) og phase (**PM**).

- Vinkel modulation, $A(t) = A_{c0}$
  - *phase modulation, AM* 2.1
  - *frequency modulation, PM* 2.2

$$y(t) = A_{c0} \cos(\omega_c t + \beta x(t)) \tag{2.1}$$

$$y(t) = A_{c0} \cos(\omega_c t + \phi(t)) \tag{2.2}$$

The change in phase, changes the frequency of the modulated wave. The frequency of the wave also changes the phase of the wave.



Figur 2.1: Examples of modulation waveshapes (PM and FM) from a sinusoidal baseband signal $x(t)$.

$\beta = \frac{\Delta f_{max}}{f_x}$ maximum phase deviation from the carrier phase

Δf_{max} peak frequency deviation

PM

$$\theta(t) = \omega_c t + \beta x(t) + \phi_0 \tag{2.3}$$

$x(t)$ Baseband signal

$\omega_c t$ Angle of Unmodulated carrier wave

$\beta = \frac{radian}{volt}$ Phase sensitivity (const.)

$\phi_0 = 0$ Initial angle

FM

Indirect FM

$$\theta_i(t) = \omega_c t + \beta \int x(t)dt \tag{2.4}$$

Direct FM

$$\theta_i(t) = \omega_c t + 2\pi K_V \int x(t)dt \tag{2.5}$$

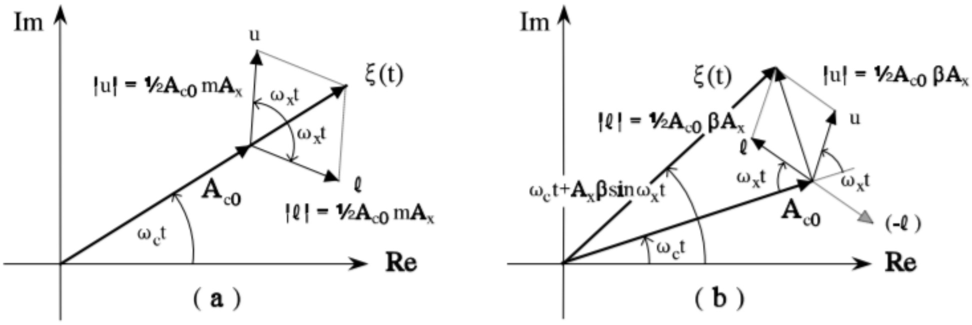
$x(t)$ Baseband signal

$\omega_c t$ Angle of Unmodulated carrier wave

$\beta\ = \frac{radian}{volt}$ Phase sensitivity (const.)

$K_V\ = \frac{hertz}{volt}$ Frequency gain (const.)

2.1.2 Phasor repræsentation



Figur 2.2: Phasor representation showing how the lower and upper sideband components, l and u, add to the carrier A_{c0} in (a) AM modulation, and (b) narrowband FM. The modulated wave becomes $y(t) = Re(\zeta)$.