HSR
HOCHSCHULE FÜR TECHNIK
RAPPERSWIL
FHO Fachhochschule Ostschweiz

Modulation

Prof. Dr. Andreas Steffen

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- Kapitel 4 Modulationsarten (Seiten 2-7)
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  - Abschnitt 4.2.2 Kohärente AM-Demodulation
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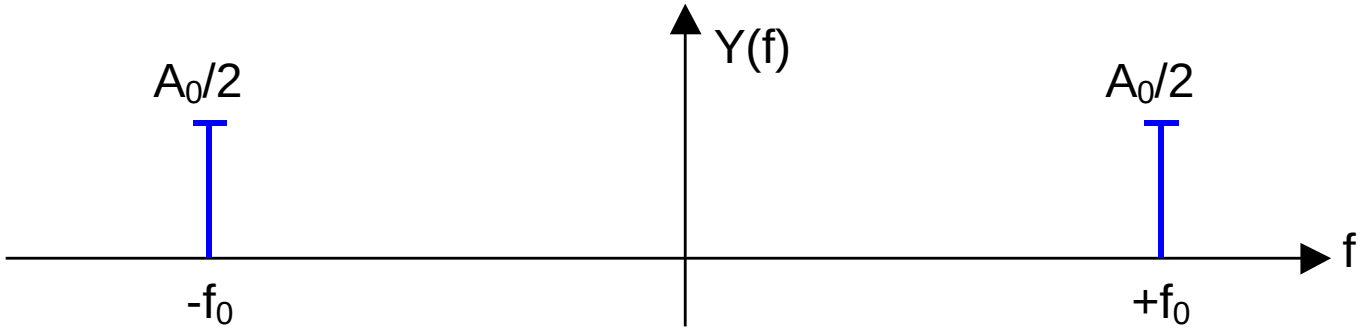
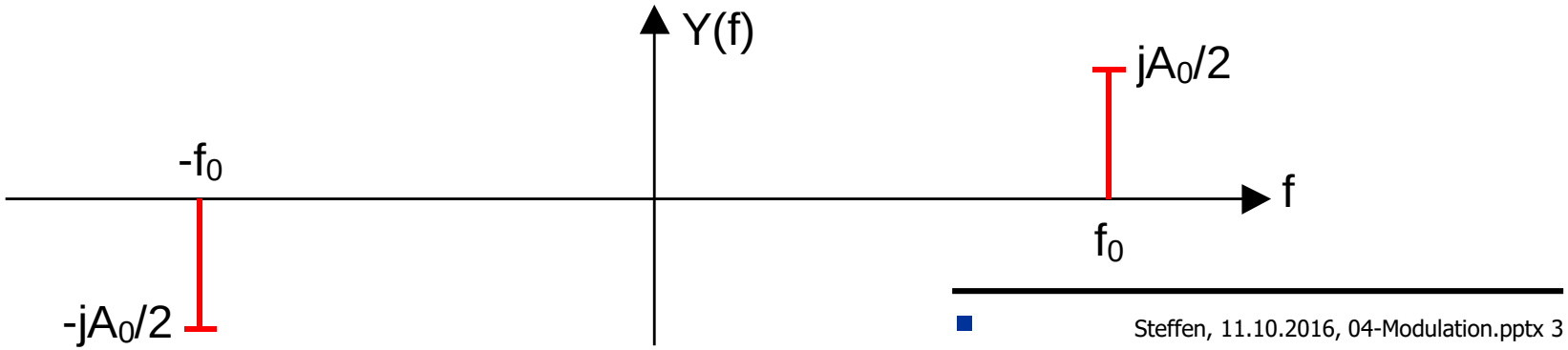
Zweiseitiges Spektrum eines Trägersignals



$$y(t) = A_0 \cos(2\pi f_0 t) = A_0 \frac{e^{j2\pi f_0 t} + e^{-j2\pi f_0 t}}{2} = \frac{A_0}{2} e^{j2\pi f_0 t} + \frac{A_0}{2} e^{-j2\pi f_0 t}$$

$$y(t) = -A_0 \sin(2\pi f_0 t) = -A_0 \frac{e^{j2\pi f_0 t} - e^{-j2\pi f_0 t}}{2j} = j\frac{A_0}{2} e^{j2\pi f_0 t} - j\frac{A_0}{2} e^{-j2\pi f_0 t}$$



Modulation eines Trägersignals

$$y(t) = a(t)\cos[2\pi f_0 t + \varphi(t)]$$

$$a(t) = f[s(t)] \quad \text{und} \quad \varphi(t) = \varphi_0$$

Amplitudenmodulation

$$a(t) = A_0 \quad \text{und} \quad \varphi(t) = f[s(t)]$$

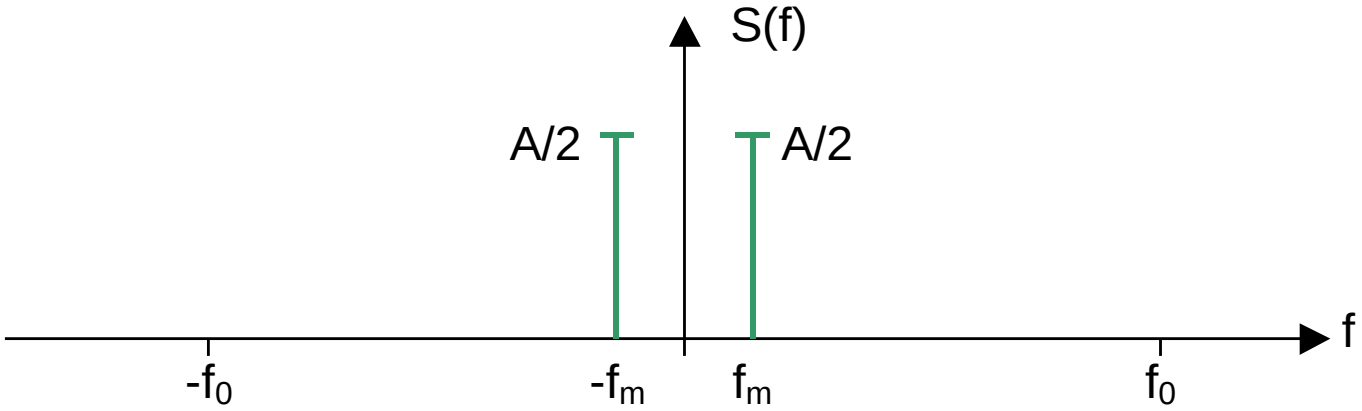
Winkelmodulation*

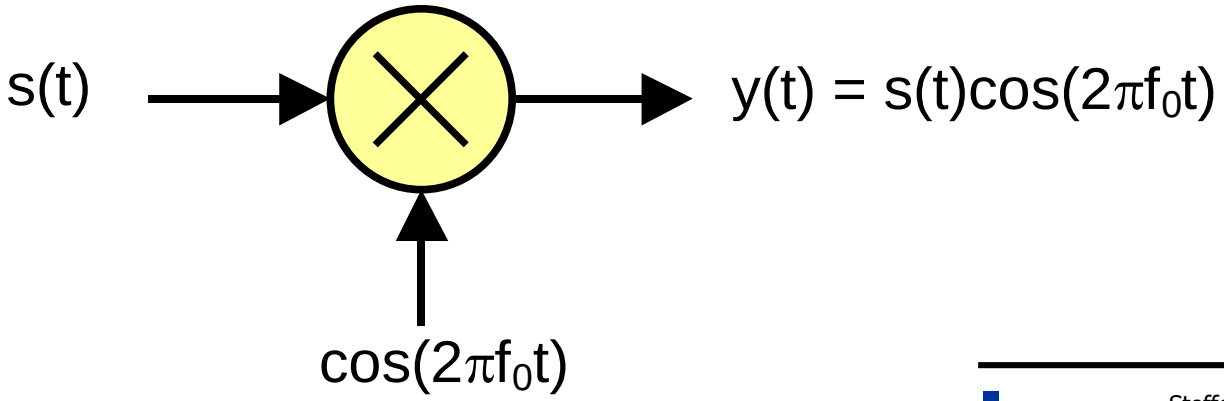
** Phasen- oder Frequenzmodulation*

Amplitudenmodulation I

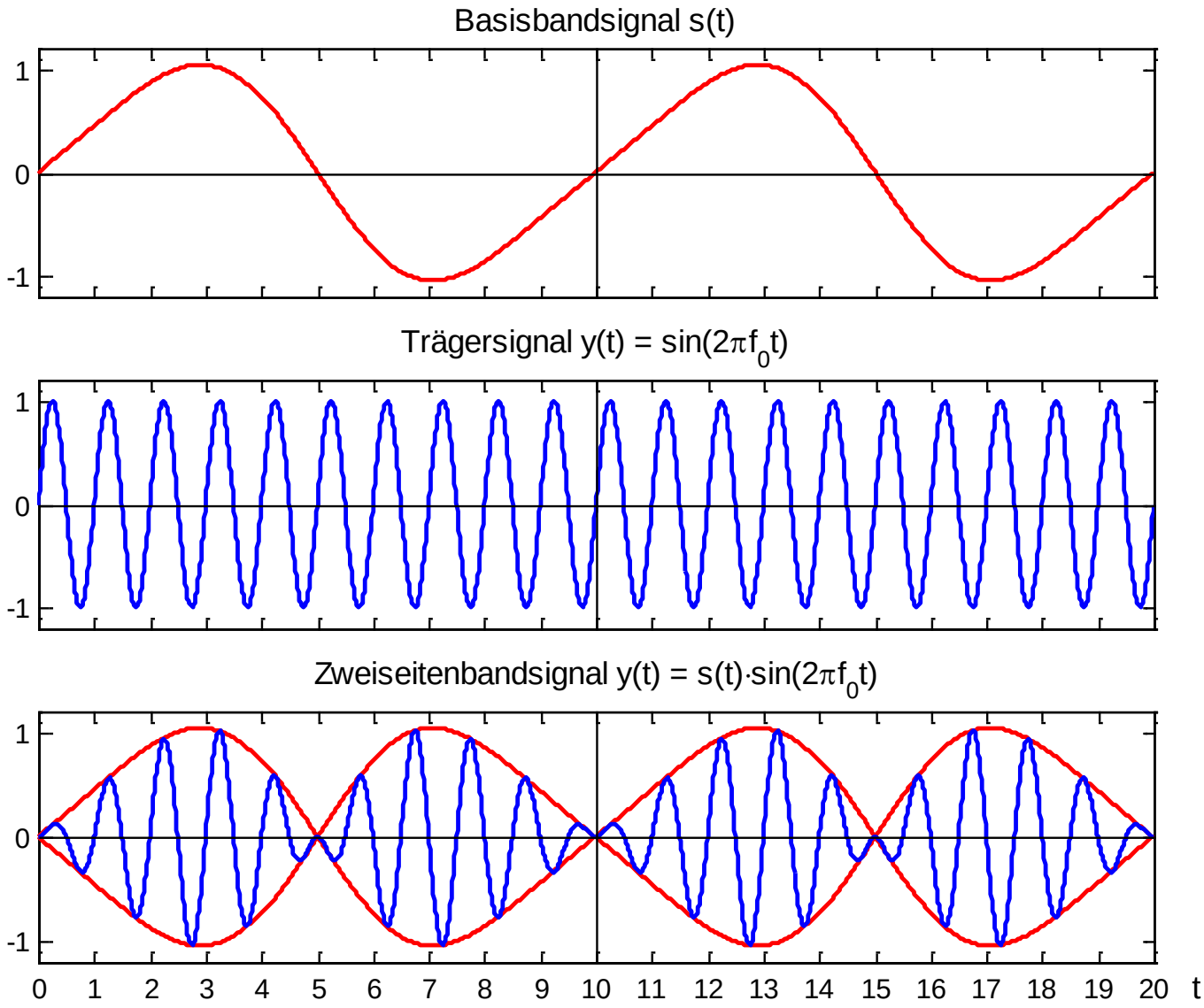
$$s(t) = A\cos(2\pi f_m t)$$

$$f_m << f_0$$





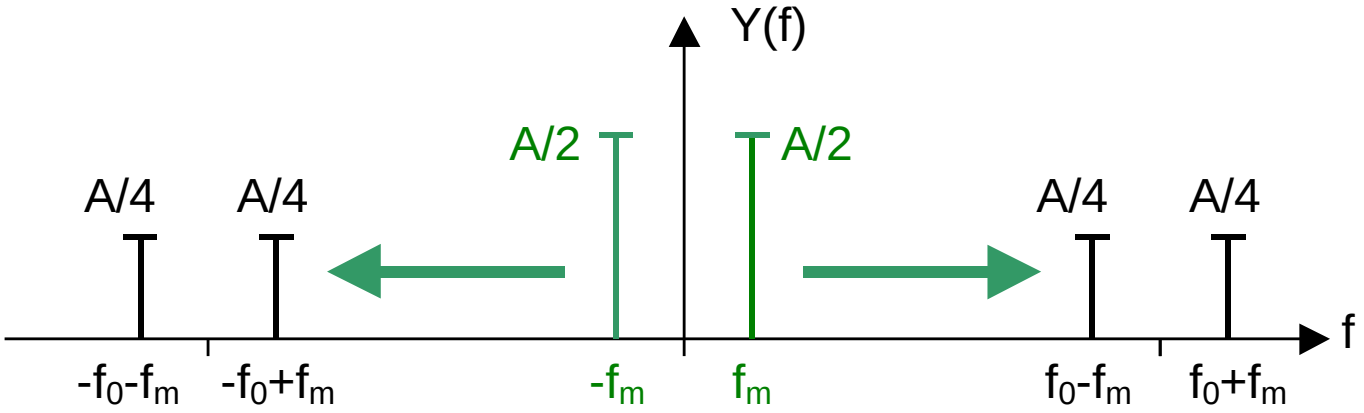
Beispiel einer Amplitudenmodulation



Amplitudenmodulation II

$$y(t) = s(t)\cos(2\pi f_0 t) = \frac{A}{2}\left(e^{j2\pi f_m t} + e^{-j2\pi f_m t}\right)\frac{1}{2}\left(e^{j2\pi f_0 t} + e^{-j2\pi f_0 t}\right)$$

$$y(t) = \frac{A}{4}\left(e^{-j2\pi(f_0+f_m)t} + e^{-j2\pi(f_0-f_m)t} + e^{j2\pi(f_0-f_m)t} + e^{j2\pi(f_0+f_m)t}\right)$$



$$Y(f) = \frac{1}{2}S(f - f_0) + \frac{1}{2}S(f + f_0)$$

Vermutung!

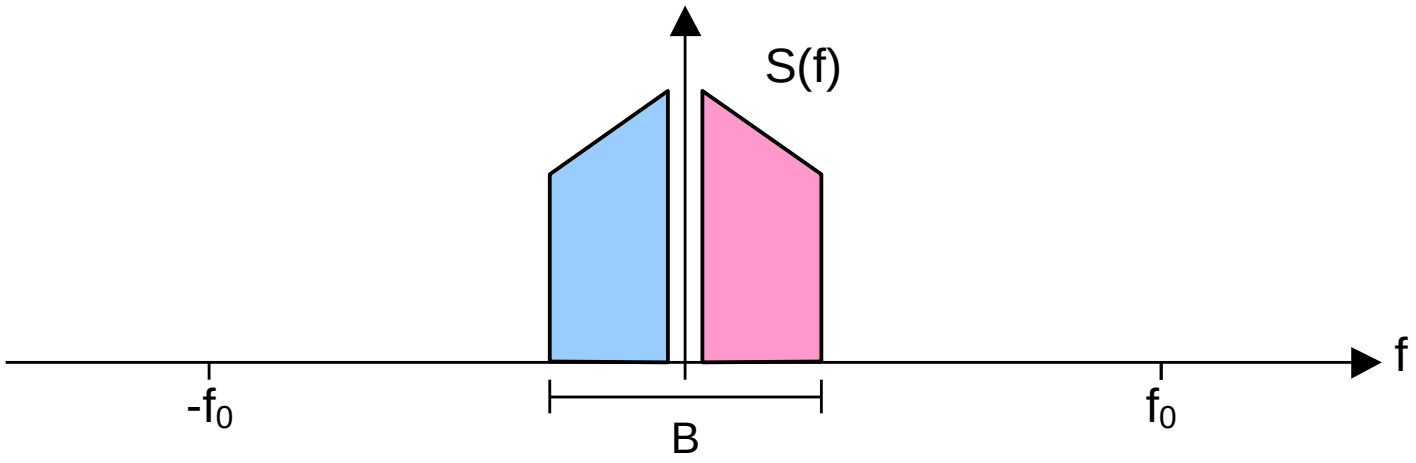
Frequenztranslation des Basisbandsignals

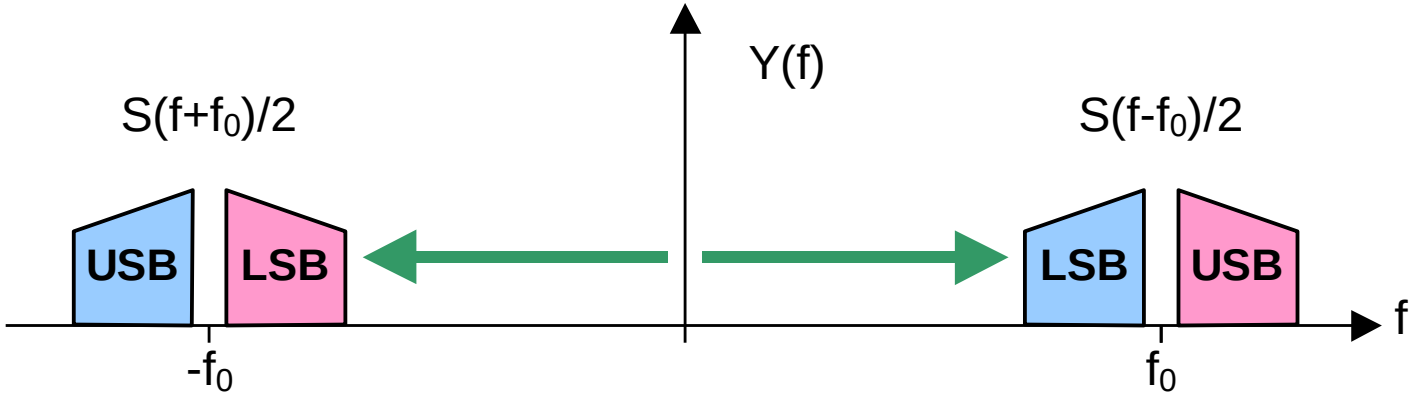
$$Y(f) = \int_{-\infty}^{\infty} y(t)\, e^{-j2\pi ft}\, dt = \int_{-\infty}^{\infty} s(t)\cos(2\pi f_0 t)\, e^{-j2\pi ft}\, dt$$

$$Y(f) = \frac{1}{2}\int_{-\infty}^{\infty} s(t)\, e^{j2\pi f_0 t} e^{-j2\pi ft}\, dt + \frac{1}{2}\int_{-\infty}^{\infty} s(t)\, e^{-j2\pi f_0 t} e^{-j2\pi ft}\, dt$$

$$Y(f) = \frac{1}{2}\underbrace{\int_{-\infty}^{\infty} s(t)\, e^{-j2\pi (f-f_0)t}\, dt}_{S(f-f_0)} + \frac{1}{2}\underbrace{\int_{-\infty}^{\infty} s(t)\, e^{-j2\pi (f+f_0)t}\, dt}_{S(f+f_0)}$$

Oberes und Unteres Seitenband



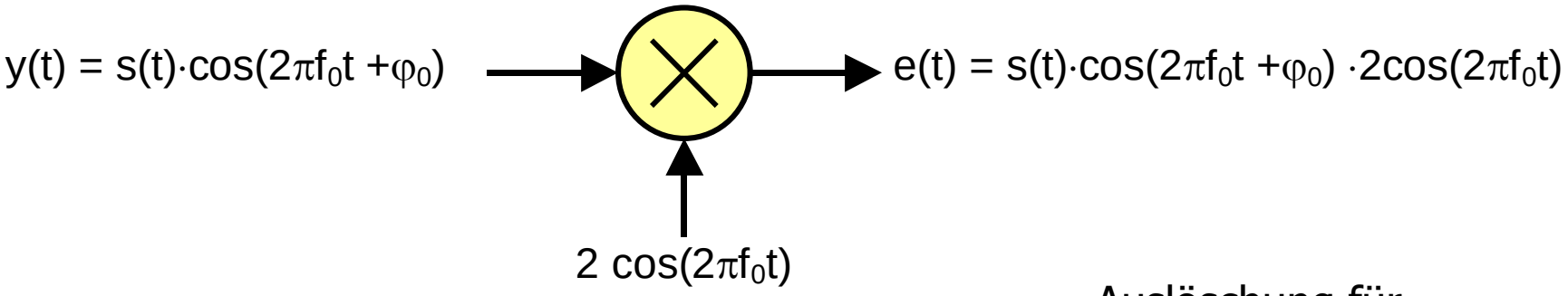


LSB: Lower Side Band

USB: Upper Side Band

Doppelter Bandbreitenbedarf:
B/2 ➔ B

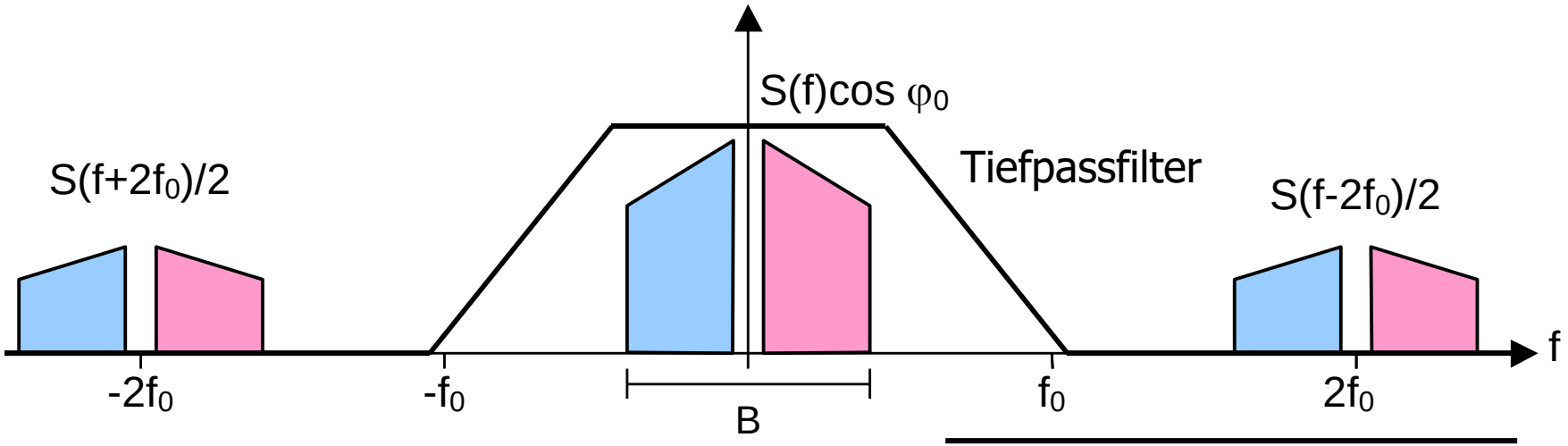
Kohärenter Produktdemodulator



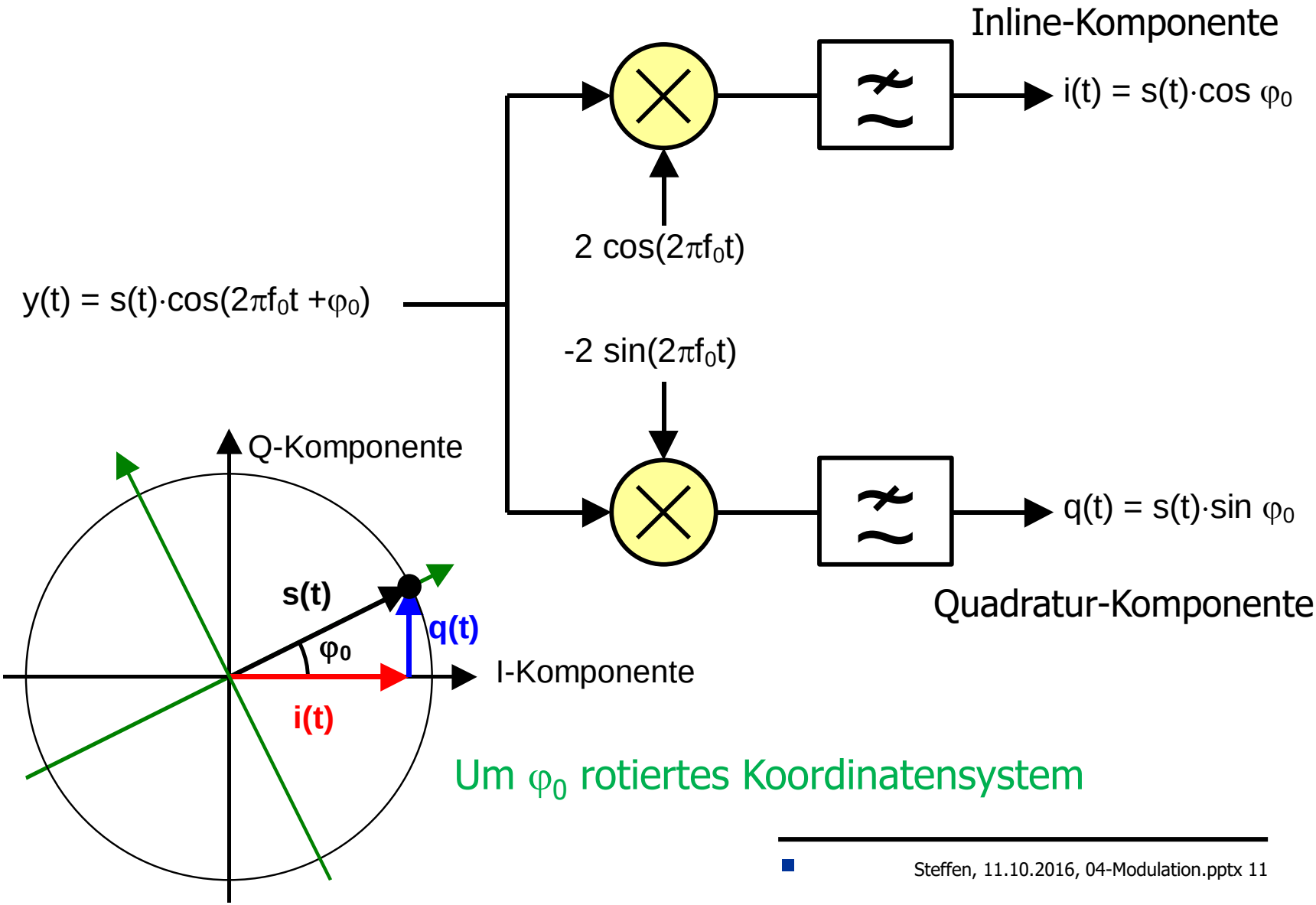
$$e(t) = s(t)\cos\varphi_0 + s(t)\cos(4\pi f_0 t + \varphi_0)$$

Auslöschung für

$$\varphi_0 = \pm\frac{\pi}{2}$$



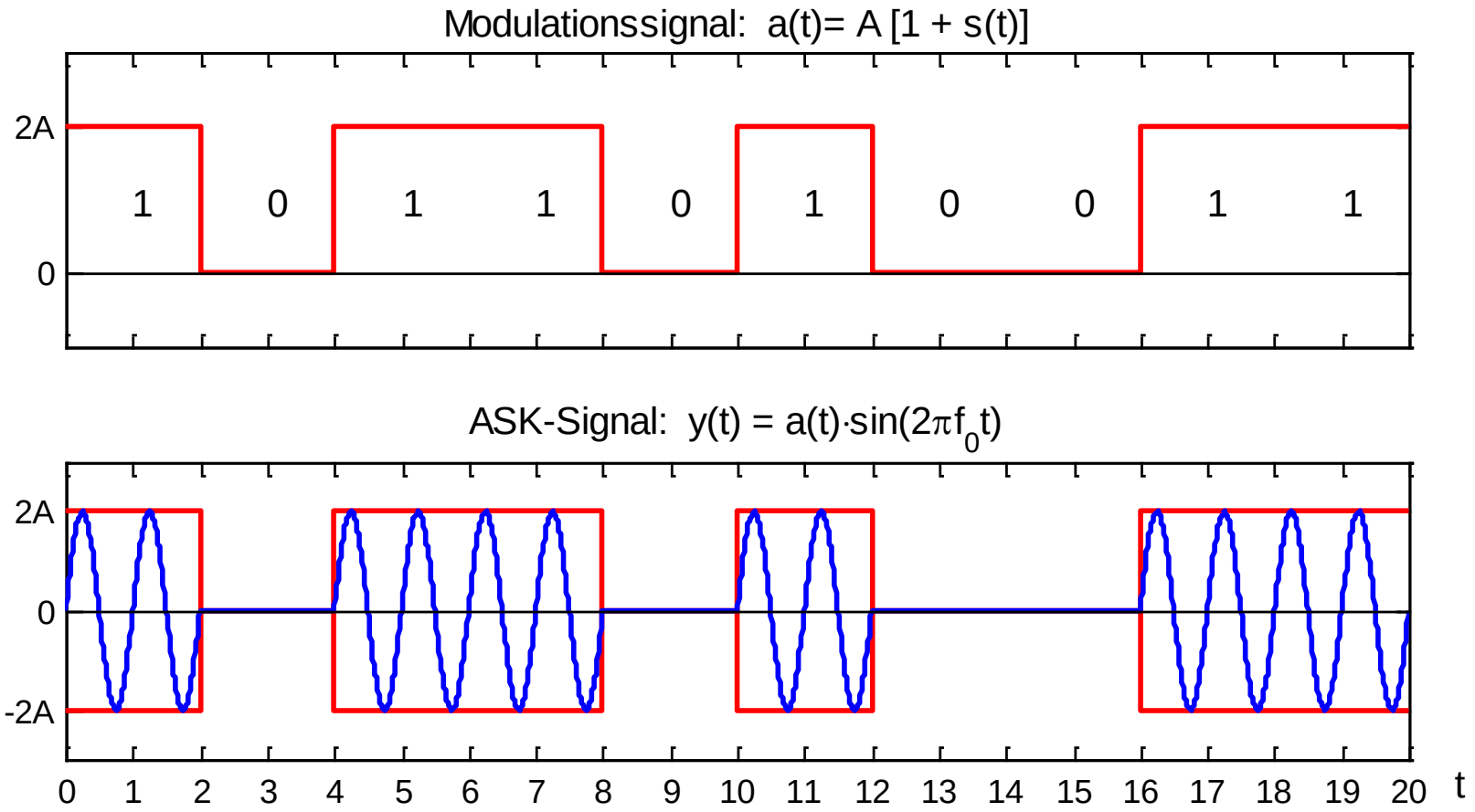
Quadratur-Demodulation

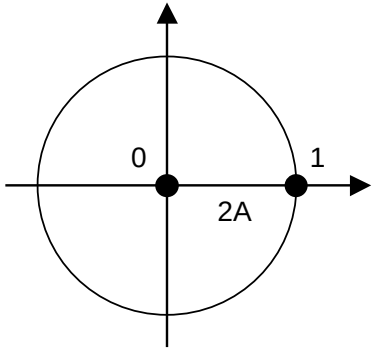


Um φ_0 rotiertes Koordinatensystem

Digitale Modulationsverfahren

Amplitudenumtastung (ASK)

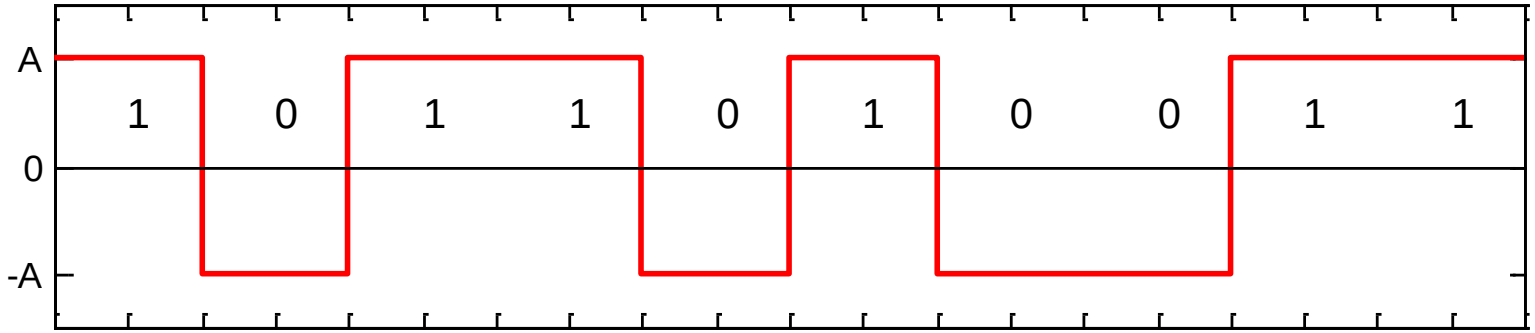




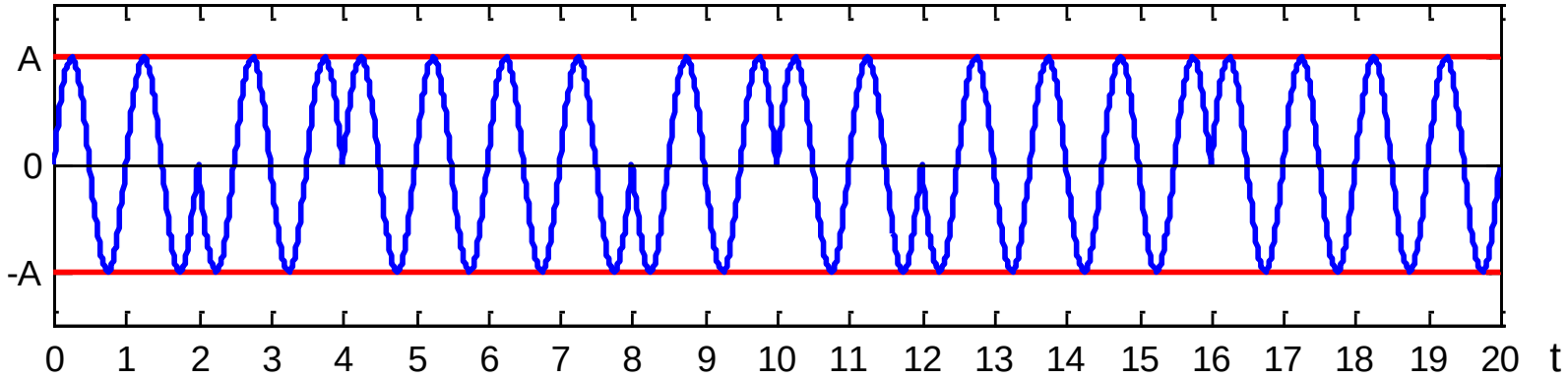
$$S = \frac{1}{2}(0 + 4A^2) = 2A^2$$

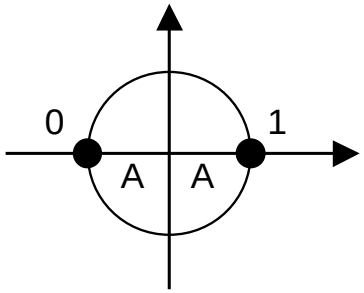
Phasenumtastung (PSK)

Modulationssignal: $a(t)= A \cdot s(t)$



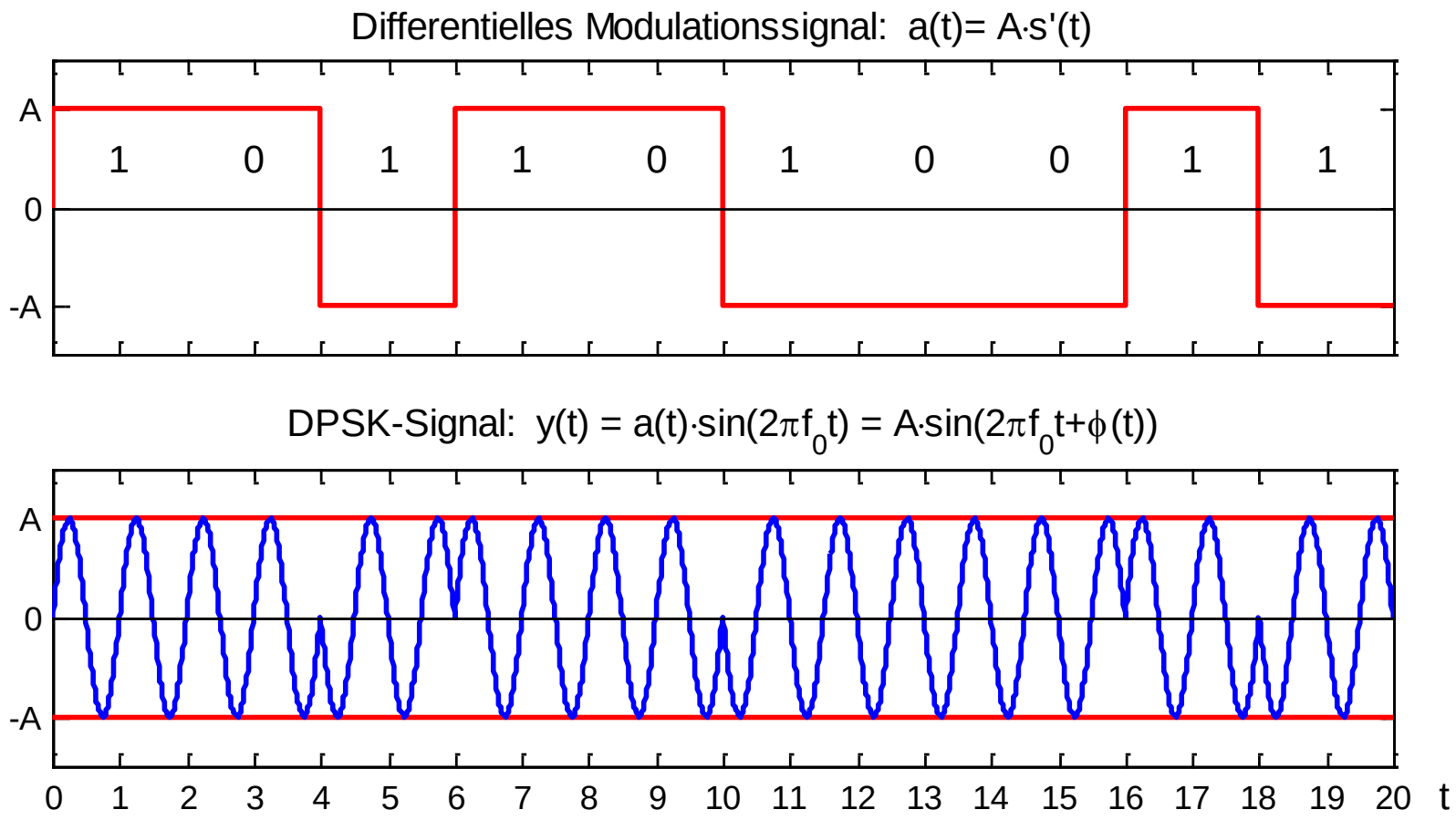
PSK-Signal: $y(t) = a(t) \cdot \sin(2\pi f_0 t) = A \cdot \sin(2\pi f_0 t + \phi(t))$

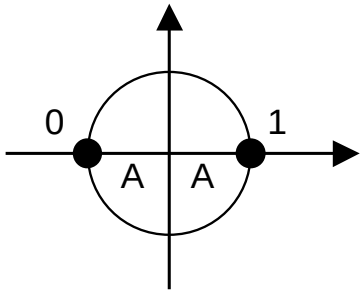




$$S = A^2$$

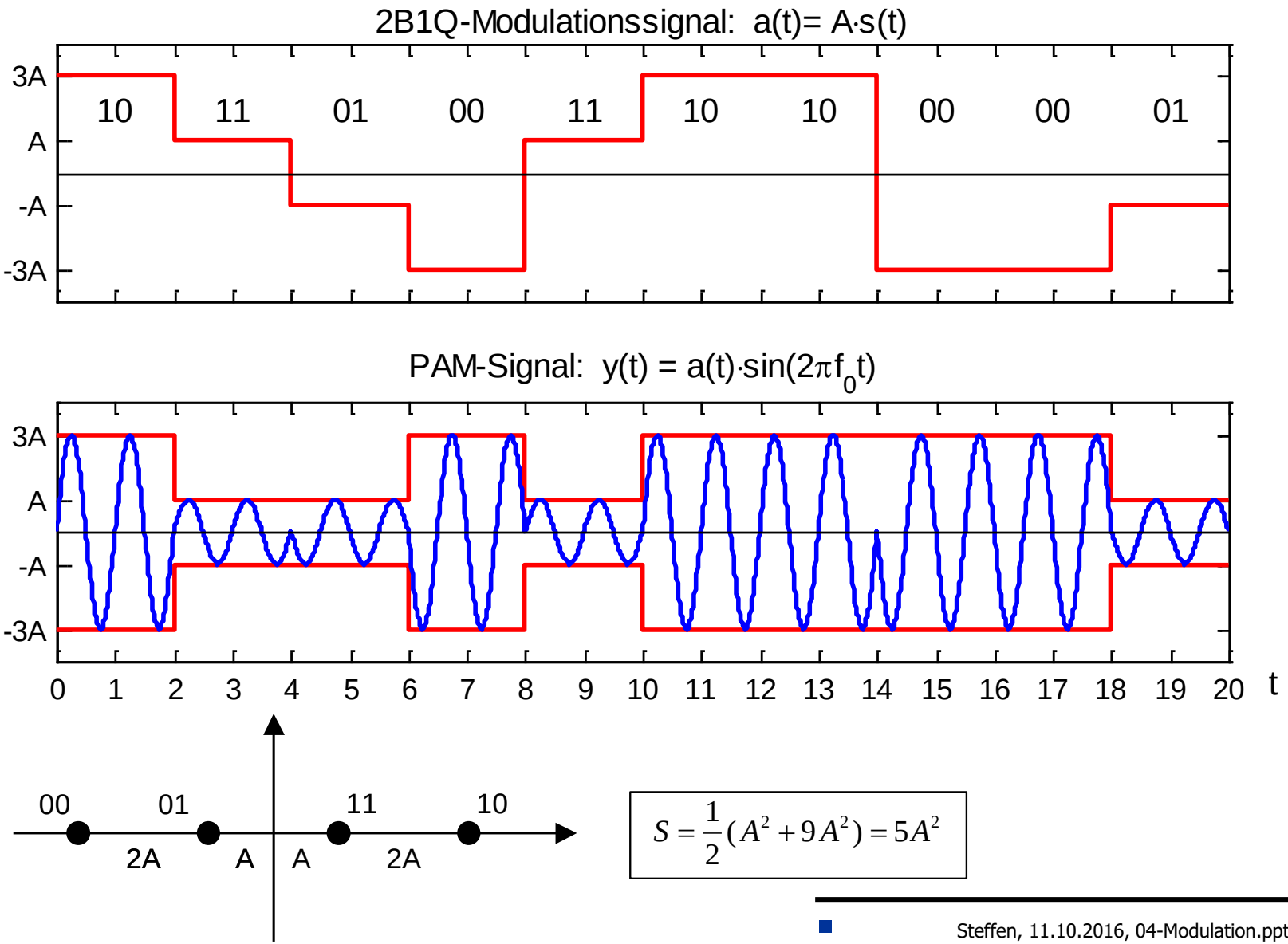
Differentielle Phasenumtastung (DPSK)





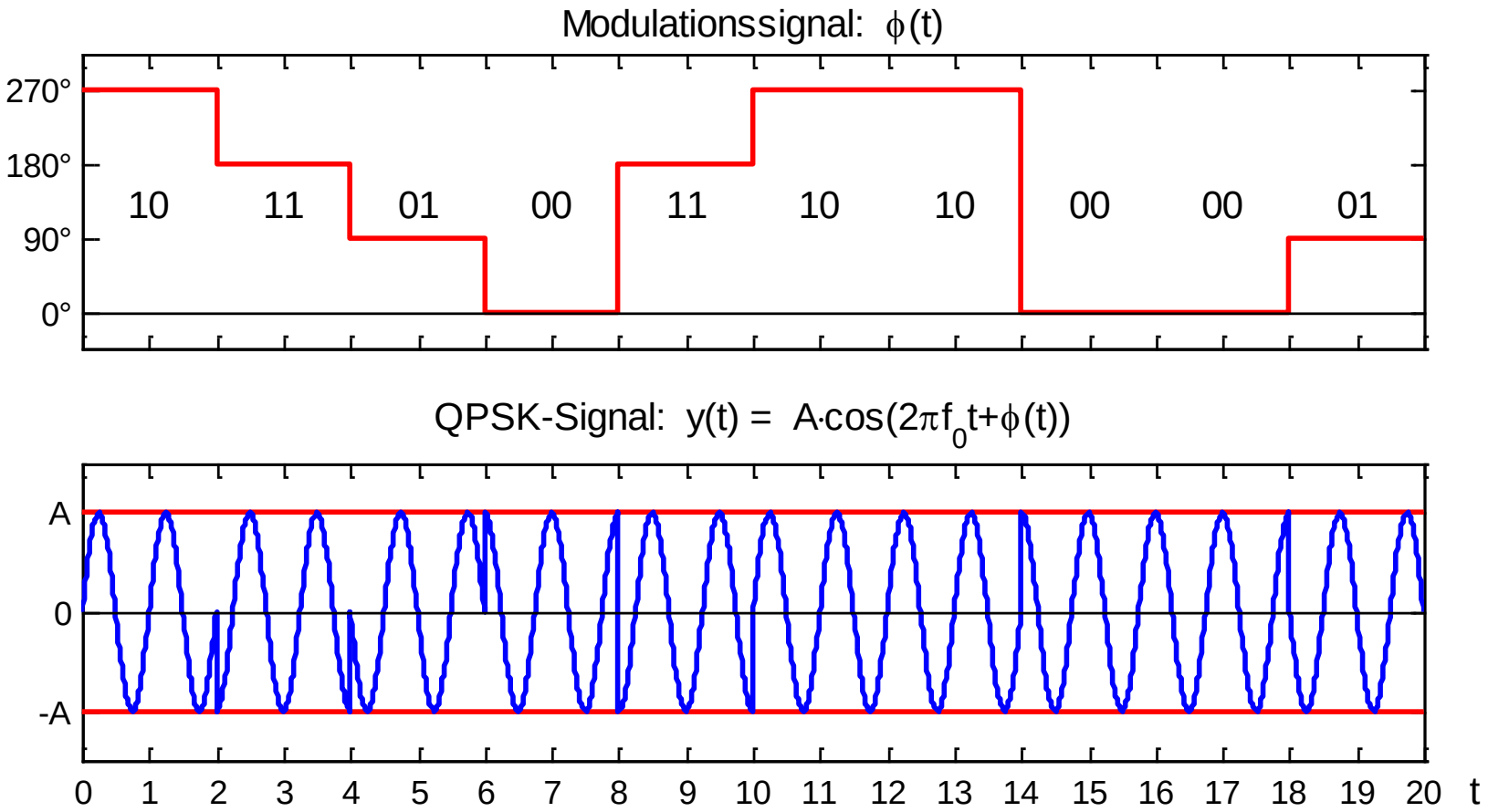
$$S = A^2$$

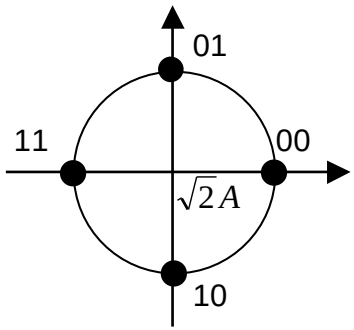
Mehrstufige Amplitudenumtastung (PAM)



$$S = \frac{1}{2}(A^2 + 9A^2) = 5A^2$$

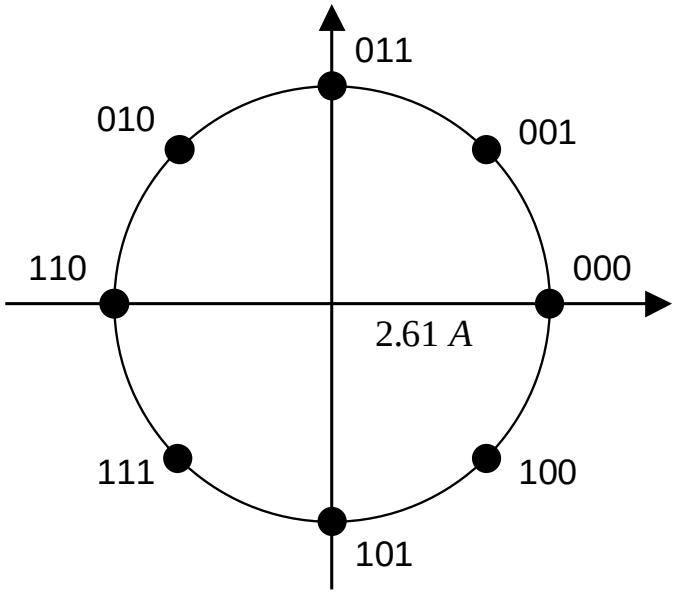
Mehrstufige Phasenumtastung (QPSK)





$$S = 2A^2$$

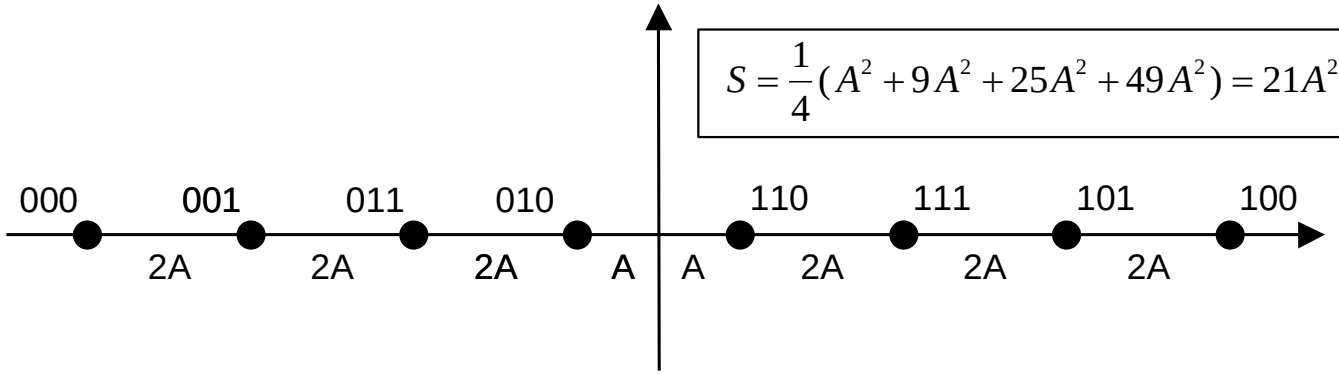
Leistungsbilanz: PSK versus PAM



$$S = 6.83A^2$$

Grey-Code:

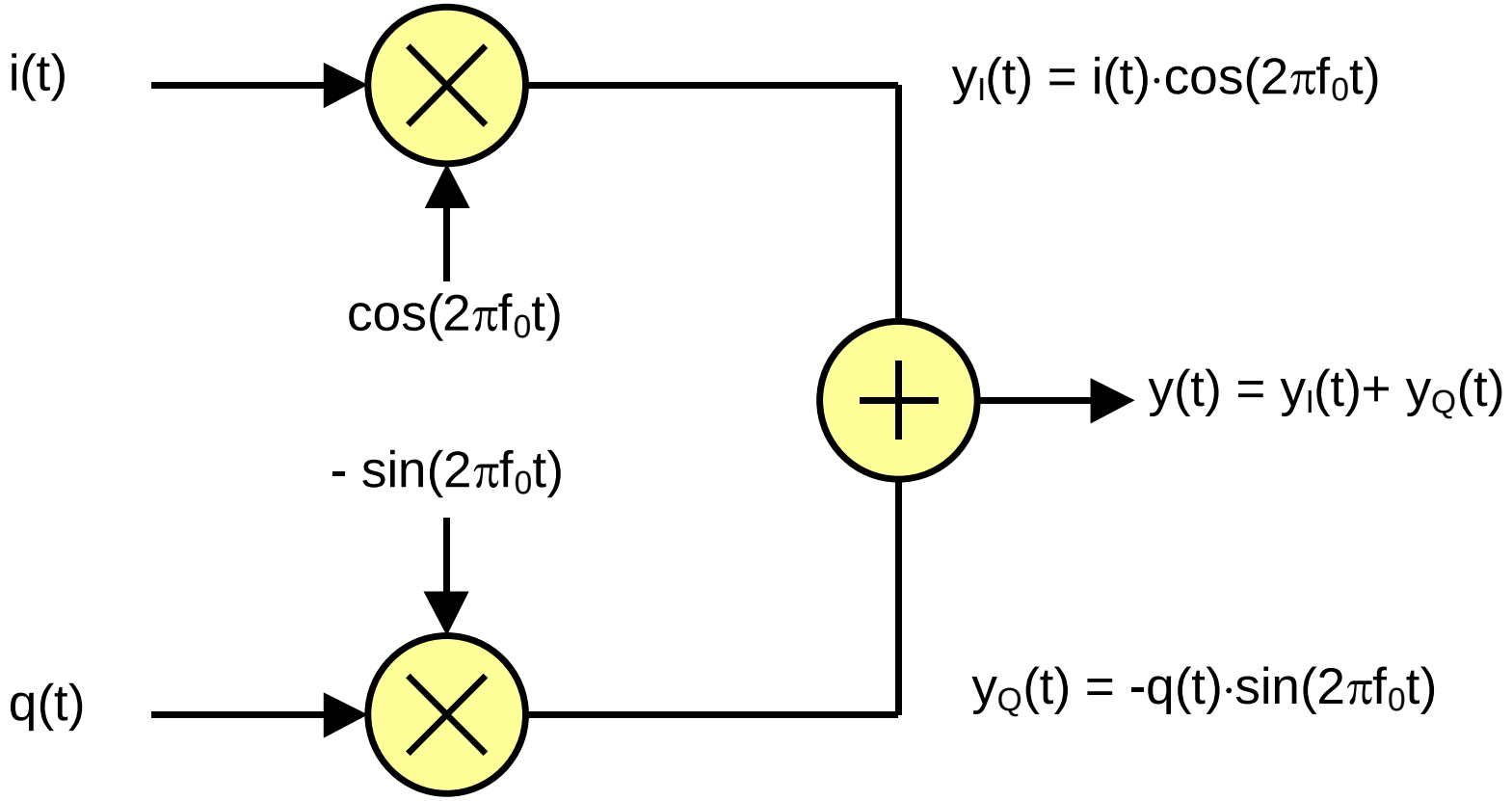
Robustheit gegen Bitfehler



$$S = \frac{1}{4}(A^2 + 9A^2 + 25A^2 + 49A^2) = 21A^2$$

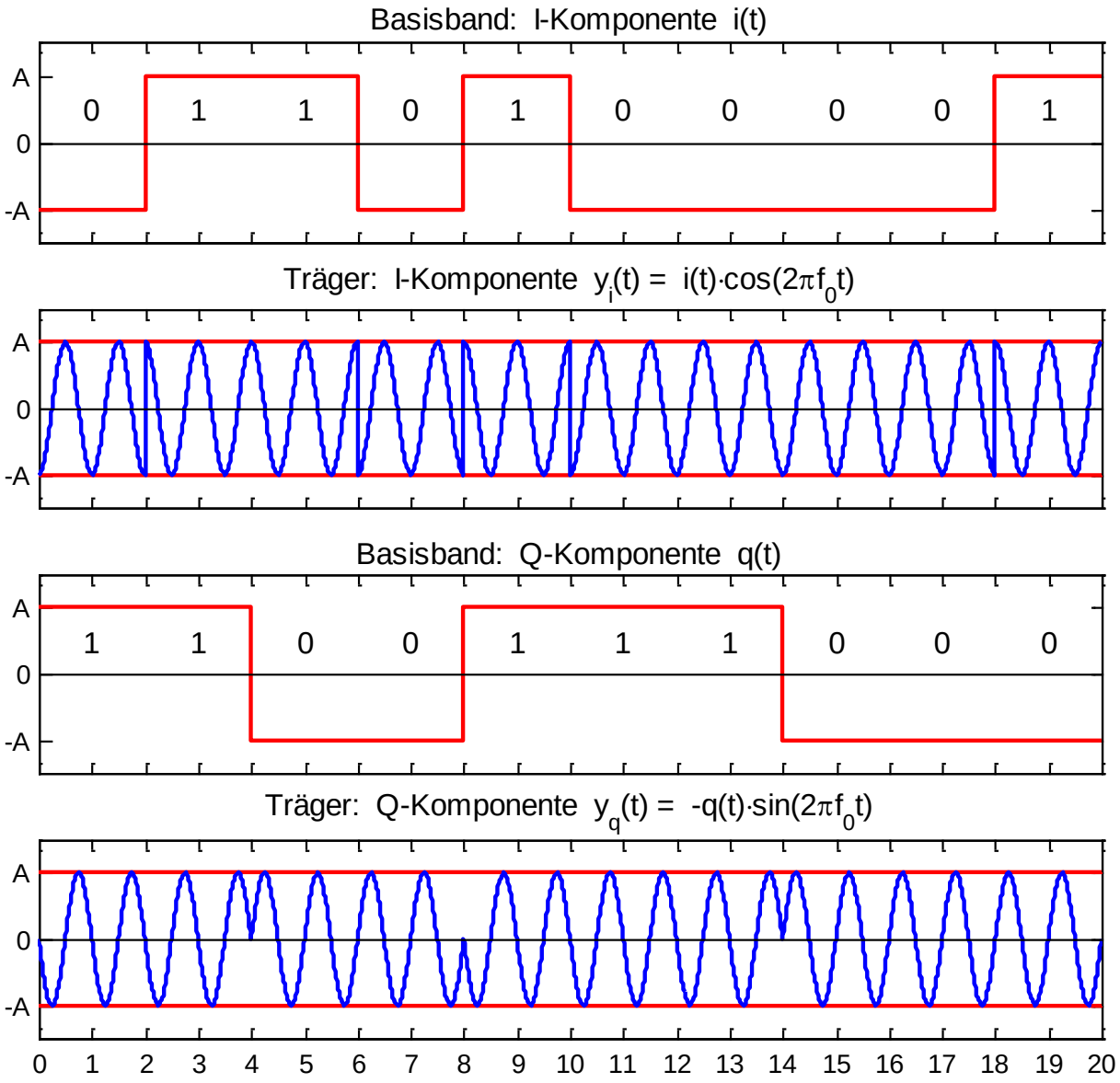
Quadratur-Amplitudenmodulation (QAM)

Inline-Komponente



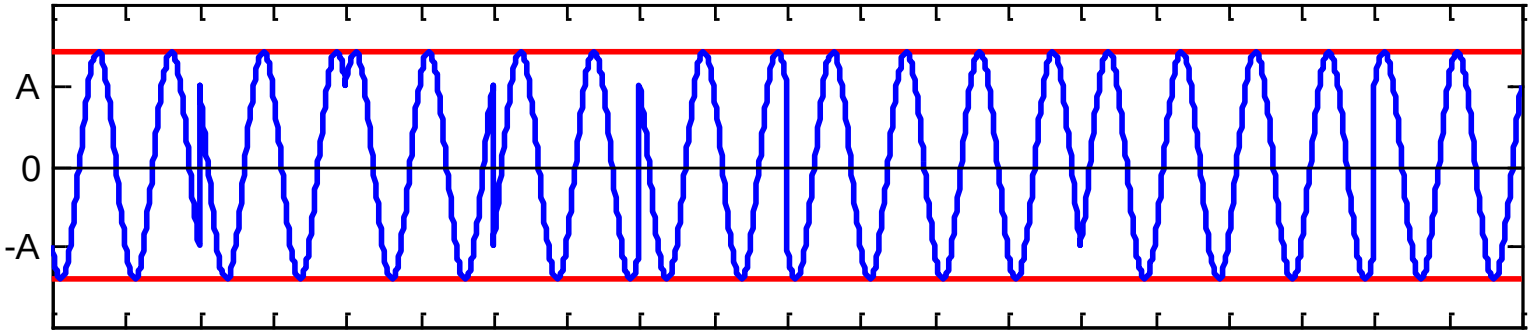
Quadratur-Komponente

QAM: Inline- und Quadratur-Komponenten

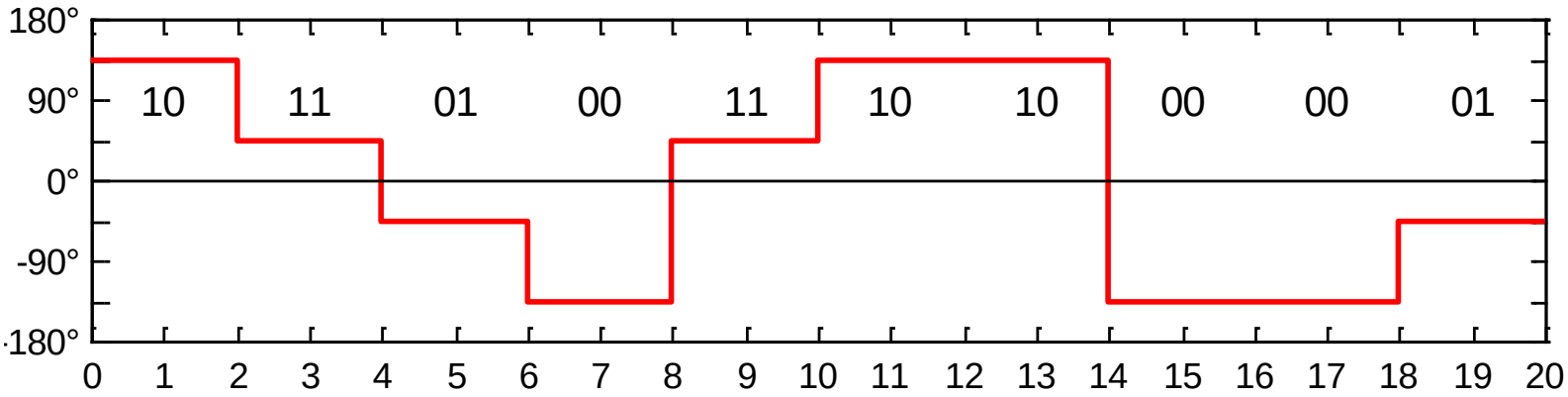


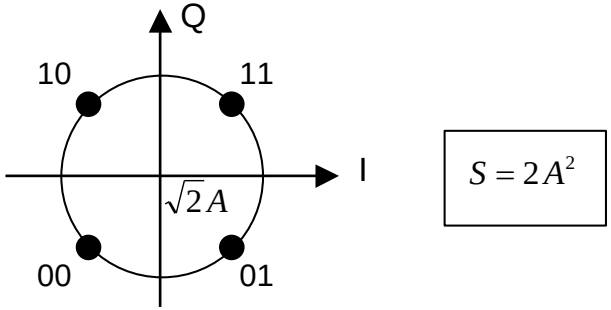
QAM-Summensignal interpretiert as QPSK

QAM-Signal: $y(t) = y_i(t) + y_q(t) = i(t)\cdot\cos(2\pi f_0 t) - q(t)\cdot\sin(2\pi f_0 t)$



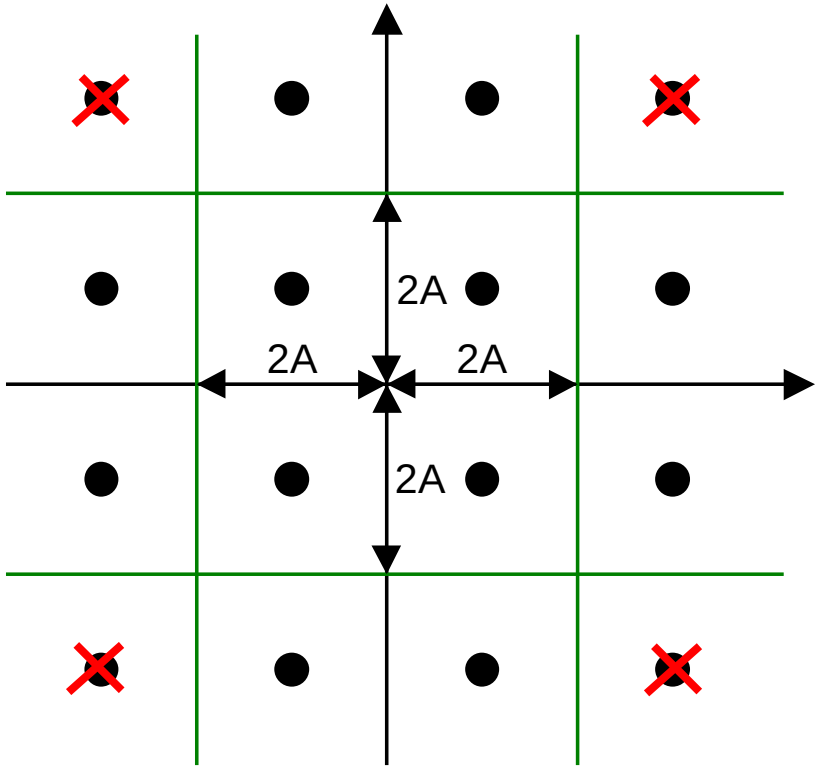
Modulationssignal: $\phi(t)$





$$S = 2A^2$$

16-QAM



Optionales Powershaping

$$S = \frac{1}{4}\left(2A^2 + 10A^2 + 10A^2 + 18A^2\right) = 10A^2$$

16-QAM: 4 Bit/Symbol

64-QAM: 6 Bit/Symbol

256-QAM: 8 Bit/Symbol

1024-QAM: 10 Bit/Symbol

4096-QAM: 12 Bit/Symbol

16384-QAM: 14 Bit/Symbol