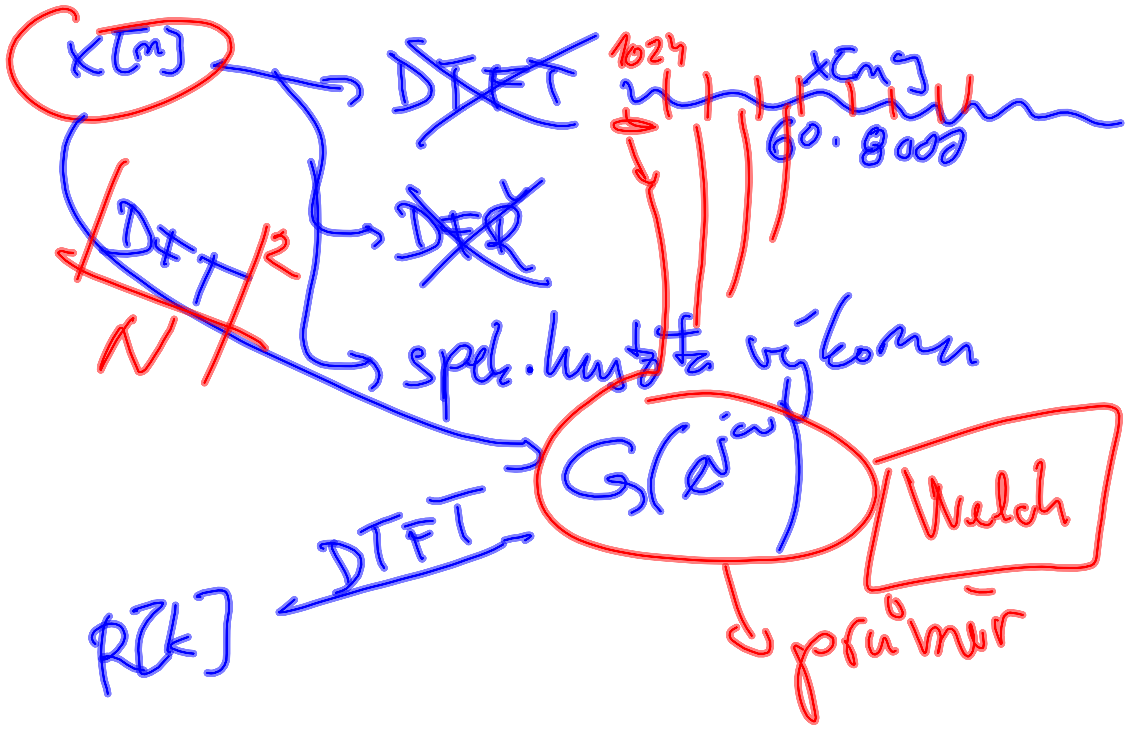
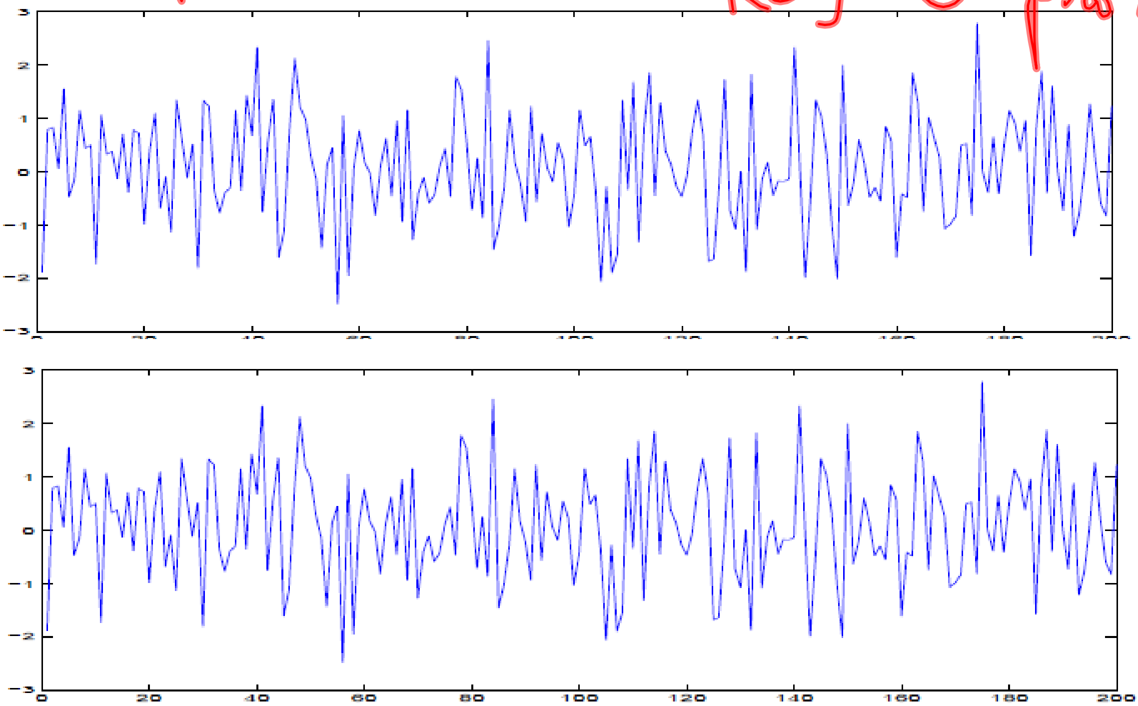

x[n]
DTFT
1024
x[n]
60 · 8000
DFT
N²
spek. hustota výkonu
G(e^{jω})
Welch
DTFT
R[k]
průměr

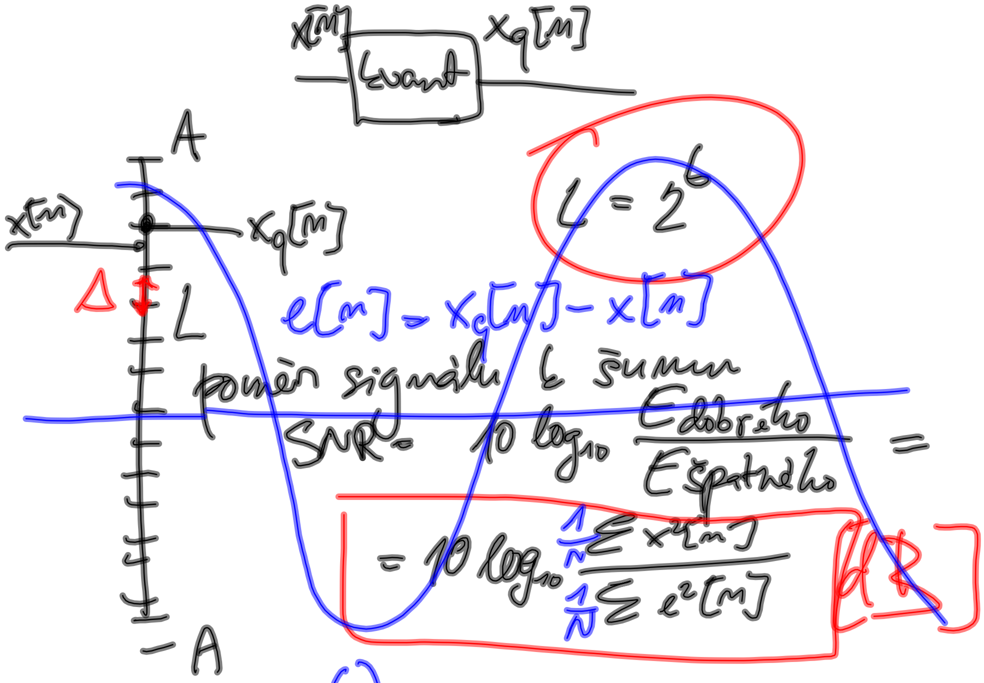
$$x[n] \xrightarrow{\cancel{X(e^{j\omega})}} \boxed{H(e^{j\omega})} \longrightarrow \cancel{Y(e^{j\omega}) = X(e^{j\omega}) \cdot H(e^{j\omega})}$$

$G_x(e^{j\omega})$

$$\boxed{G_y(e^{j\omega}) = G_x(e^{j\omega}) \left|H(e^{j\omega})\right|^2}$$

$R[0] = \text{V. k. č.}$ $R[k] = 0$ pro $k \neq 0$



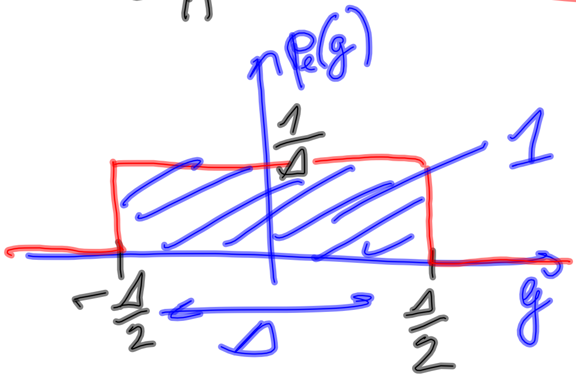


$e[n] = x_q[n] - x[n]$

poměr signálu k šumu

$$SNR = 10\log_{10}\frac{E_{dobrého}}{E_{špatného}} = \boxed{= 10\log_{10}\frac{\frac{1}{N}\sum x^2[n]}{\frac{1}{N}\sum e^2[n]}} \; [dB]$$

$L = 2^6$



Vol. $a = 0$

$P = D$

$$D = \int_{-\Delta/2}^{\Delta/2} (g-a)^2 \cdot p(g)\,dg = \frac{1}{\Delta}\int g^2\,dg = \frac{1}{\Delta}\left[\frac{g^3}{3}\right]_{-\frac{\Delta}{2}}^{\frac{\Delta}{2}} =$$

$$= \frac{1}{\Delta}\left(\frac{\left(\frac{\Delta}{2}\right)^3}{3} - \frac{\left(-\frac{\Delta}{2}\right)^3}{3}\right) = \frac{1}{\Delta}\left(\frac{\Delta^3}{8\cdot 3} + \left(+\frac{\Delta^3}{8\cdot 3}\right)\right) =$$

$$= \frac{2\cdot\Delta^2}{24} = \boxed{\frac{\Delta^2}{12}} - P_e$$

užitečný signál – amplituda A, cos

$$P_s = \frac{A^2}{2} = \frac{L^2\Delta^2}{4\cdot 2} = \frac{L^2\Delta^2}{8}$$

$2A = L\Delta$

$A = \frac{L\Delta}{2}$

$L = 2^6$

$$SNR = 10\log_{10}\frac{\frac{L^2\cancel{\Delta^2}}{8}}{\frac{\cancel{\Delta^2}}{12}} = 10\log_{10}\frac{3}{2}L^2 =$$

$$= 10\log_{10}\frac{3}{2}2^{2\cdot 6}$$

0. Frekvence

ANALOG $x(t)$ | $x[n]$ DIGITÁL

f [Hz] $\frac{\text{perioda}}{s}$ | F_s | f' [ ]

$\omega = 2\pi f$ $\frac{rad}{s}$ | $f' = \frac{f}{F_s}$

$\omega' = \frac{\omega}{F_s}$ [rad]

1. FREKVENČNÍ ANALÝZA

výsledek = množství konstant · sumační op. · vstup · $e^{\pm j \cdot \text{čas} \cdot \text{frekvence}}$ (báze)

čas → frekvence

frekvence → čas

ANALOG $x(t)$ — FT

$$X(j\omega) = \int_{-\infty}^{\infty} x(t) e^{-j\omega t} dt$$

$$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(j\omega) e^{+j\omega t} d\omega$$

$X(j\omega) = X^*(-j\omega)$

$x(t-\tau)$

$X(j\omega) \cdot e^{-j\omega\tau}$

DIGITÁL $x[n]$ — DTFT

$$\tilde{X}(e^{j\omega}) = \sum_{n=-\infty}^{\infty} x[n] \cdot e^{-j\omega n}$$

$\frac{2\pi f}{F_s} = \frac{2\pi F_s}{F_s} = 2\pi$

$$x[n] = \frac{1}{2\pi} \int_{-\pi}^{\pi} \tilde{X}(e^{j\omega}) e^{+j\omega n} d\omega$$

$\tilde{X}(e^{j\omega}) = \tilde{X}^*(e^{-j\omega})$

$\tilde{X}(e^{j\omega}) = \tilde{X}(e^{j(\omega + 2k\pi)})$

$x[n-k]$

$\tilde{X}(e^{j\omega}) \cdot e^{-j\omega k}$

PERIODICKÉ

$x(t)$ T_1 — FŘ

$\omega_1 = \frac{2\pi}{T_1}$

$$c_k = \frac{1}{T_1} \int_0^{T_1} x(t) e^{-jk\omega_1 t} dt$$

∞ možných koeficientů

$c_k = c_{-k}^*$

$x(t-\tau)$

$c_k \cdot e^{-jk\omega_1 \tau}$

$x[n]$ N — DFŘ

$\omega_1 = \frac{2\pi}{N}$

$$\tilde{X}[k] = \sum_{n=0}^{N-1} x[n] e^{-jnk\frac{2\pi}{N}}$$

0, $\frac{2\pi}{N}$, …, $N-1$, 2π

N koeficientů

$\tilde{X}[k] = \tilde{X}^*[-k]$

$\tilde{X}[k] = \tilde{X}[k + m \cdot N]$

$\tilde{X}[k] = \tilde{X}^*[N-k]$

$\tilde{x}[n-m_1]$

$\tilde{X}[k] \cdot e^{-jk\frac{2\pi}{N}m_1}$

DFT

$$X[k] = \sum_{n=0}^{N-1} x[n] \cdot e^{-jnk\frac{2\pi}{N}} \quad k = 0 \ldots N-1$$

DFT pro výpočet analogu:

1. może počítání: $k \leq \frac{N}{2}$
2. Vzorkovací teorém
3. (FŘ) N musí obsahovat celý násobek T_1

2. SYSTÉMY

ANALOG

$$\sum_{k=0}^{Q} b_k \frac{d^k x(t)}{dt^k} = \sum_{k=0}^{P} a_k \frac{d^k y(t)}{dt^k}$$

diferenciální rovnice

$\delta(t) \to$ systém $\to h(t)$ imp. odezva

$x(t) \to \boxed{h(t)} \to y(t)$

$$y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(\tau) h(t-\tau) d\tau$$

$$H(j\omega) = \int_{-\infty}^{\infty} h(t) e^{-j\omega t} dt$$

Laplace

$$\sum b_k X(s) s^k = \sum a_k Y(s) s^k$$

$$H(s) = \frac{\sum b_k s^k}{\sum a_k s^k}$$

přenosová funkce

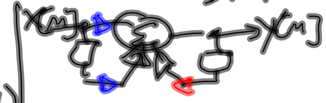
$s \to j\omega$

$H(j\omega)$

freqs

$$H(s) = \frac{\Pi (s-n_1) \cdots (s-n_Q)}{\Pi (s-p_1) \cdots (s-p_P)}$$

DIGITÁL



C-code

$$y[n] = \sum_{k=0}^{Q} b_k x[n-k] - \sum_{k=1}^{P} a_k y[n-k]$$

diferenční rovnice

$\delta[n] \to$ syst $\to h[n]$

$x[n] \to \boxed{h[n]} \to y[n]$

$$y[n] = x[n] * h[n] = \sum_{k=-\infty}^{\infty} x[k] h[n-k]$$

$$H(e^{j\omega}) = \sum_{n=-\infty}^{\infty} h[n] e^{-j\omega n}$$

Z - transformace

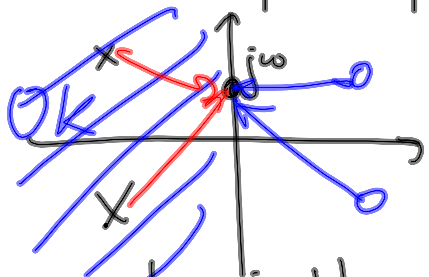
$$Y(z) = \sum_{k=0}^{Q} b_k X(z) z^{-k} - \sum_{k=1}^{P} a_k Y(z) z^{-k}$$

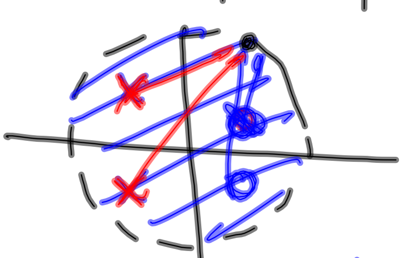
$$H(z) = \frac{\sum_{k=0}^{Q} b_k z^{-k}}{1 + \sum_{k=1}^{P} a_k z^{-k}}$$

$z \to e^{j\omega}$

freqz

$$H(z) = \frac{\Pi (z-n_1) \cdots (z-n_Q)}{\Pi (z-p_1) \cdots (z-p_P)}$$





$$\left| H\begin{pmatrix} j\omega \\ \text{nebo} \\ e^{j\omega} \end{pmatrix} \right| = \frac{\text{součin délek modrých vek.}}{\text{součin délek červených vek.}}$$

$$\arg H\begin{pmatrix} j\omega \\ \text{nebo} \\ e^{j\omega} \end{pmatrix} = \text{Součet úhlů modrých vek.} - \text{Součet úhlů červ. vek.}$$

PÁ 5. 1.

~~10:00 – 12:00~~

16:00 – 18:00