ch ≠ AWGN ch
Have to be concerned about ISI as well

\[ P(f) = H_{\text{TX}}(f) H_{\text{CH}}(f) H_{\text{RX}}(f) \]
no ISI \implies P(f), Nyquist
In practice, \( P(f) = P_{\text{Rec}}(f) \)

AWGN ch \rightarrow h_{\text{TX}}(t) = c s(t-T_p) (\text{ideal ch})

\[ h_{\text{TX}}(t) = h_{\text{RX}}(\pi t) \]
\[ |H_{\text{RX}}(f)| = |H_{\text{TX}}(f)| \]
SRRC = RRC = RC

\[ \sqrt{P_{\text{rec}}(f)} \]

- \[ h_{\text{eff}}(f) = 1 \]
- \[ h_{\text{in}}(f) = \delta(f) \]
- No ISI (ISI removed)
- Best protection against noise

* \( h_{\text{eff}}(f) \neq 1 \rightarrow \) Nyquist X

Ax. Equalization

\[ \frac{1}{P_{\text{rec}} h_{\text{eff}}} \neq \frac{1}{P_{\text{rec}} h_{\text{in}}} \]

\( ISI \) is removed completely

But, ultimate noise suppression (MF) in disturbed

\[ \frac{1}{P_{\text{rec}} h_{\text{eff}}} \neq \frac{1}{P_{\text{rec}} h_{\text{in}}} \]

\[ \sqrt{P_{\text{rec}} h_{\text{eff}}} \neq \sqrt{P_{\text{rec}} h_{\text{in}}} \]

\[ \text{Noise amplification, due to aggressiveness in removing ISI} \]

Best strategy: Desing an equalizer (\( h_{\text{eff}}(f) \)) which will remove as much ISI as possible, while maintaining SRRC at the same time as much as possible.
Causality violated -> time shift

Infinite tails -> truncation of signal duration ~ 10T

Practical \( h_{\text{pr}}(t) \)

Nyquist (1928)

\[ R \left[ \text{bits/sec} \right] = \frac{\text{sym/ sec}}{\text{Hz}} \times \log_2 (1 + \text{SNR}) \text{ bits/sym} \]

Shannon (1948)

70-year-old active research field

In practice:

AMC

Adaptive modulation and coding

\[ R = \frac{k}{n} \ll 1 \text{ ...encoder rate} \]

K = number of channel codes

n = number of encoder output bits
Q: 16.64 kM, convolutional code rate \( r = \frac{2}{3} \)

SRRC with \( \alpha = 0.25 \)

\[ f(SNR) \]

\[ B_w = 2 \text{ MHz} \]

Find transmission rate

\[ R = 2 \times 10^6 \text{ b/s} \times \frac{1}{1 + 0.25} \times \frac{5}{12} \times \frac{3}{3} \times 4 \times 10^6 \]

\[ = \frac{2 \times 5}{3} \times \frac{2}{3} \times 4 \times 10^6 \]

\[ = \frac{64}{15} \text{ Mbps/Sec} \]
\[ R_{\text{max}} = \frac{n B \log_2 (1 + \text{SNR})}{\min(\# \text{of TX ant, } \# \text{of RX ant})} \]

\[ \frac{P_{\text{SYN}}}{P_N} = \frac{P_h}{BN_0} = \frac{P_s}{nBN_0} \]

LTE
802.11a
\sim 1 \text{ Gbps}

WiMax
3 \text{ Gbps}

\( n = 4 \)
\( B = 100 \text{ MHz} \)
\( 64 \text{ QAM, } r = \frac{5}{6} \)

\[ \frac{5}{6} \times \frac{5}{6} \times \log_2 64 \]
\[ = 2 \text{ Gbps} \]