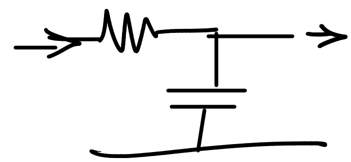
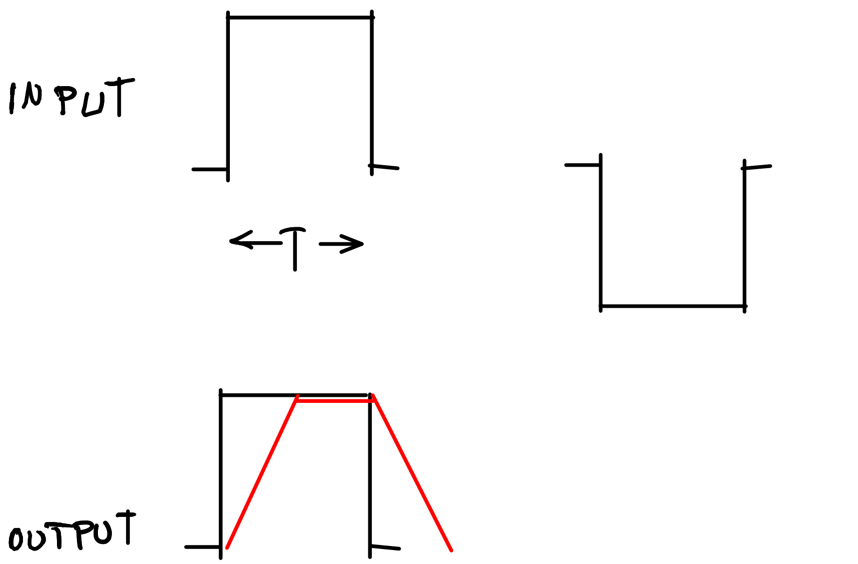
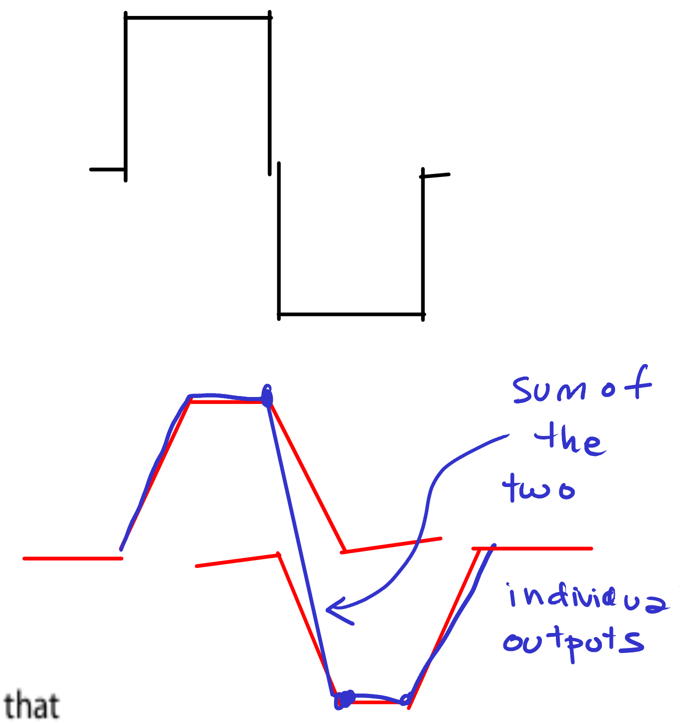
Lecture 5 - Data Transmission over Bandlimited Channels

Exercise 1: Draw a square pulse of duration T. Draw the pulse after it has passed through a linear low-pass channel that results in rise and fall times of $T/2$. Draw the output for an input pulse of the opposite polarity. Use the principle of superposition to draw the output of the channel for a positive input pulse followed by a negative input pulse.







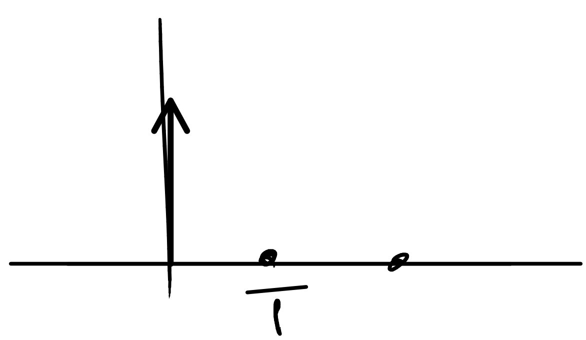
Exercise 2: What is the impulse response of a channel that does not alter its input? Does this impulse response meet the Nyquist condition? Will it result in ISI?

a channel that doesn't change the i/p

has $h(t) = \delta(t)$

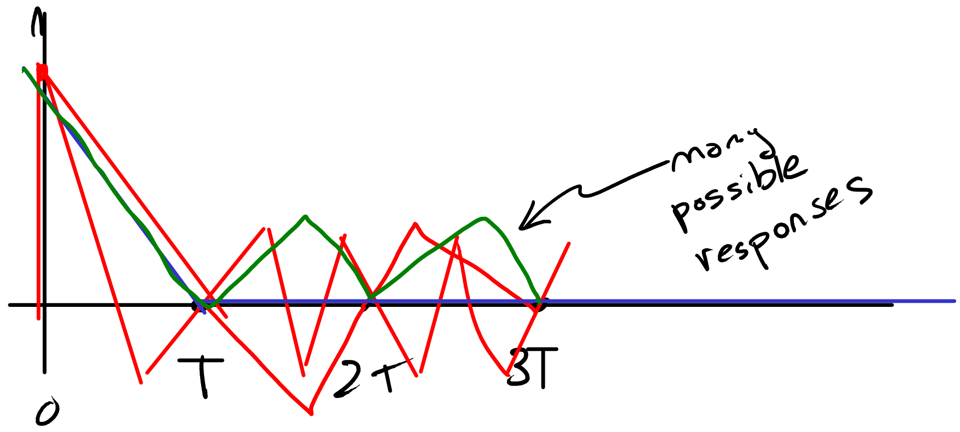
impulse response

impulse

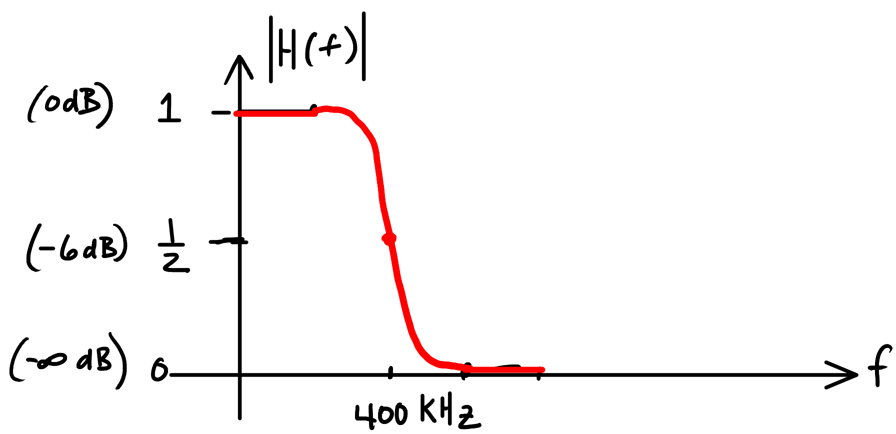


NO ISI.

Exercise 3: Draw the impulse response of a channel that meets the Nyquist condition but is composed of straight lines.



Exercise 4: Draw the (real portion of) a raised-cosine transfer function that would allow transmission of impulses at a rate of 800 kHz with no interference between the impulses.



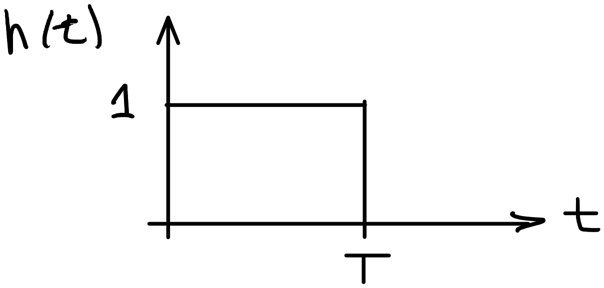
Exercise 5: Draw the impulse response of a filter than converts input impulses to pulses of duration T? What is the shape of the frequency response of this filter? *Hint: the Fourier transform of a pulse of duration T is* $\frac{\sin(\pi f T)}{\pi f}$. What is the "bandwidth" of this filter – when is it first zero? How does this compare to the "bandwidth" of the raised-cosine filter above?

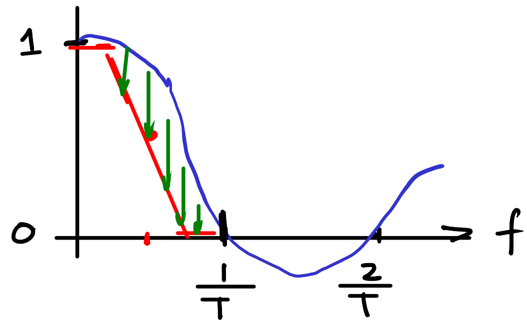
$$\pi f T = \pi$$

$$f = \frac{1}{T}$$

$$\pi f T = 2\pi$$

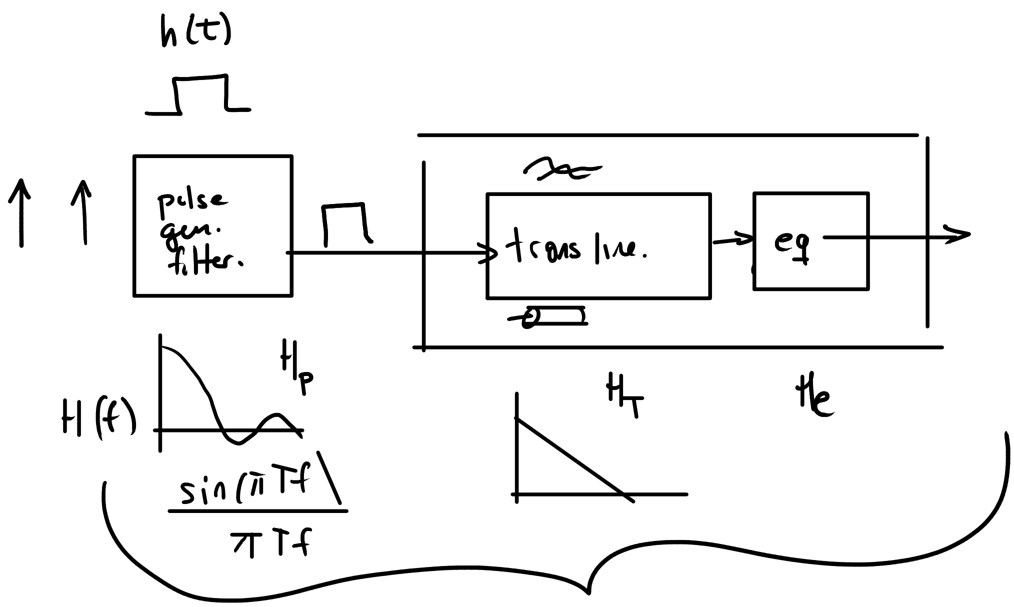
$$f = \frac{2}{T}$$

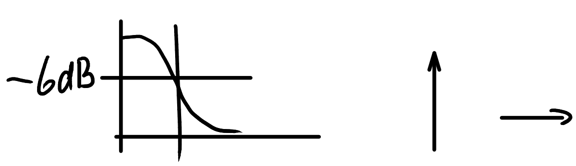




"first null bandwidth" $= \frac{1}{T}$

for RC filter $\frac{1}{2T} <$ "first null bandwidth" $\leq \frac{1}{T}$





$$H_W = H_P \cdot H_T \cdot H_e \qquad H_e = \frac{H_W}{H_P \cdot H_T}$$

Exercise 6: What is the possible range of values of α?

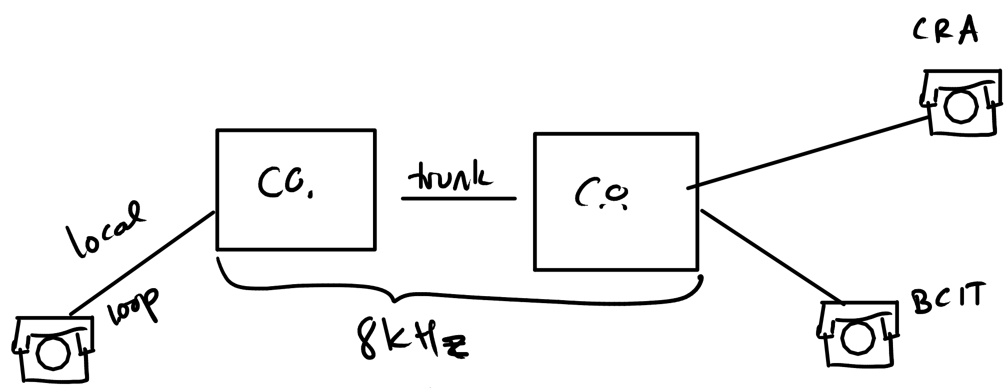
$$0 \leq \alpha \leq 1$$

Exercise 7: Could equalization be done at the receiver only? At the transmitter only? Why or why not? Which might be more practical?

Rx only: Yes.

Tx only: Yes. → only the product matters of $H_T \cdot H_{eq}$

Rx side more often because Rx can measure channel.



8kHz

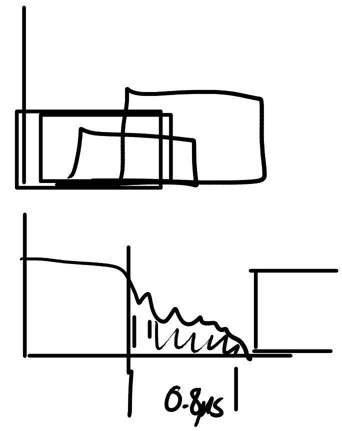
× 8 b/sample

= 64 kb/s

Exercise 8: The 802.11g WLAN standard uses OFDM with a sampling rate of 20 MHz, with $N = 64$ and guard interval of $0.8\mu s$. What is the total duration of each OFDM block, including the guard interval? How many guard samples are used?

$C = 300\ m/\mu s$

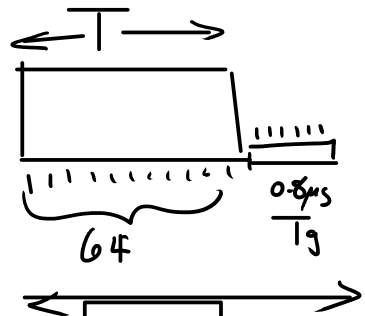
$240\ m$



$f_s = 20 \times 10^6$

$N = 64$

$T_g = 0.8\mu s$



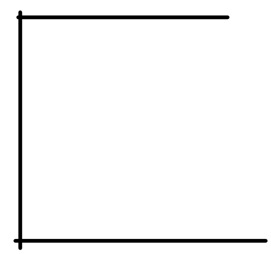
$T = \frac{64}{20\times10^6} = 3.2\mu s$ $\boxed{4\mu s.}$

$f_s = \frac{N}{T}$

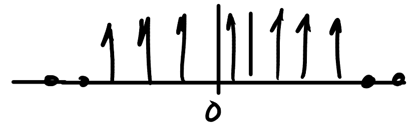
$N_g = f_s \cdot T_g = 20\times10^6 \cdot 0.8\times10^{-6} = 16.$

Bandwidth: (for complex signal) = 20 MHz

bandwidth of each sub carrier = $\frac{20}{64}$ MHz.



$\approx \frac{1}{3}$ MHz (312.5 MHz).



Exercise 9: Can we use compression to transmit data faster than the Shannon capacity? Explain.

No. Shanon capacity limits information rate (which is data rate after best possible compression).

Exercise 10: What is the channel capacity of a 3 kHz channel with an SNR of 20dB?

$B =$

$\frac{S}{N} = 20\text{dB}$

$$C = B \log_2\left(1 + \frac{S}{N}\right)$$

$$20 = 10 \log\left(\frac{S}{N}\right)$$

$$\frac{S}{N} = 10^{\frac{20}{10}} = 100$$

$$= 3 \times 10^3 \log_2(1 + 100)$$

$$\approx 3 \times 10^3 \cdot 6 \approx 20 \text{ kb/s}$$

DEG W-VIEW

3E3log$_2$(101)=

N1 19'974.63445

Exercise 11: What are some differences between the signalling rate limit imposed by the Nyquist no-ISI criteria and the Shannon Capacity Theorem?

	Nyquist no-ISI	Shanon Capacity
what is limited:	symbol rate	information rate
units	symbols/s	bit/second
depends on?	-6dB or ($\frac{1}{2}$) bandwidth	SNR, B
conditions for it to apply	symmetry in $h(t)$ or $H(f)$	AWGN "brick-wall" chanel of B/W B.