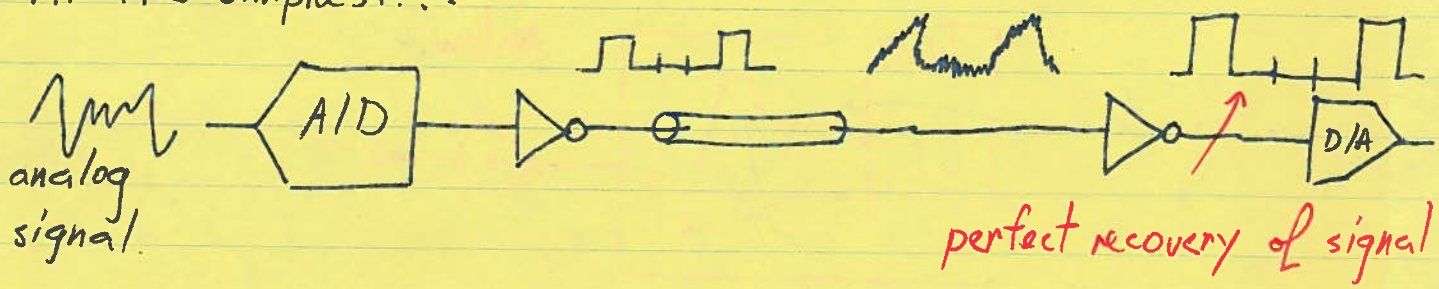
L1 Introduction to Digital Communications

1.1 Basic Ideas

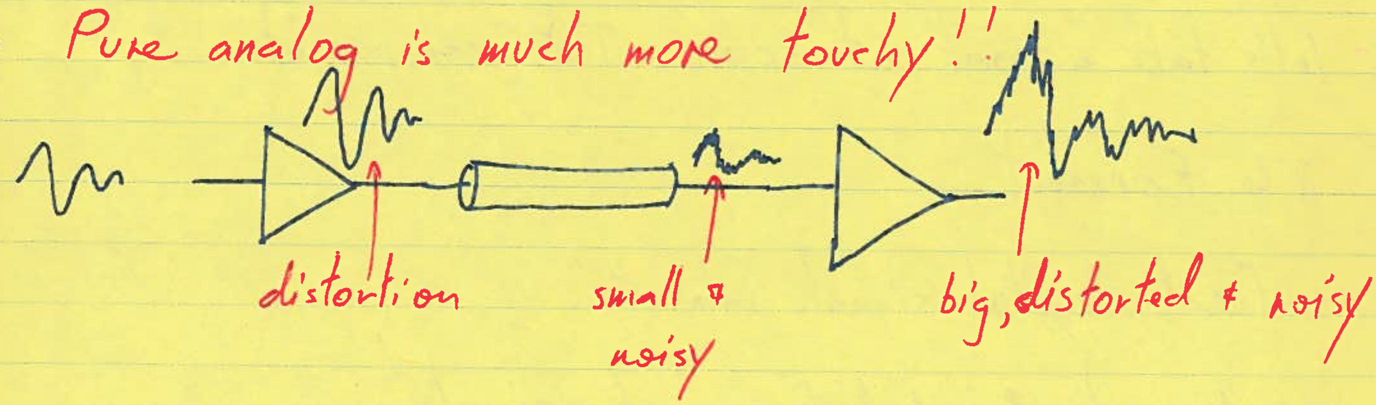
- What is digital comms? Sending signals that have been converted to 0's & 1's

- At it's simplest...



- The tremendous noise immunity of digital signals makes very robust digital comms. possible

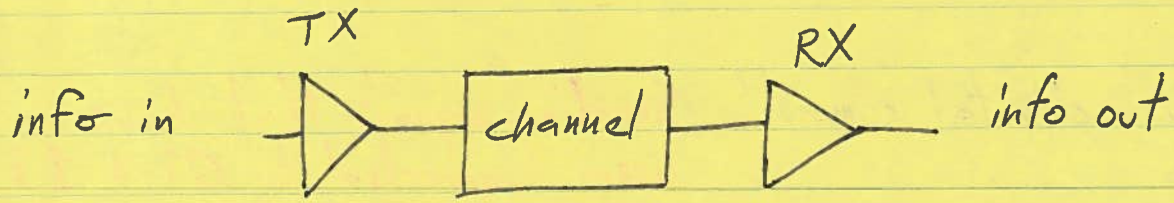
- Pure analog is much more touchy!!

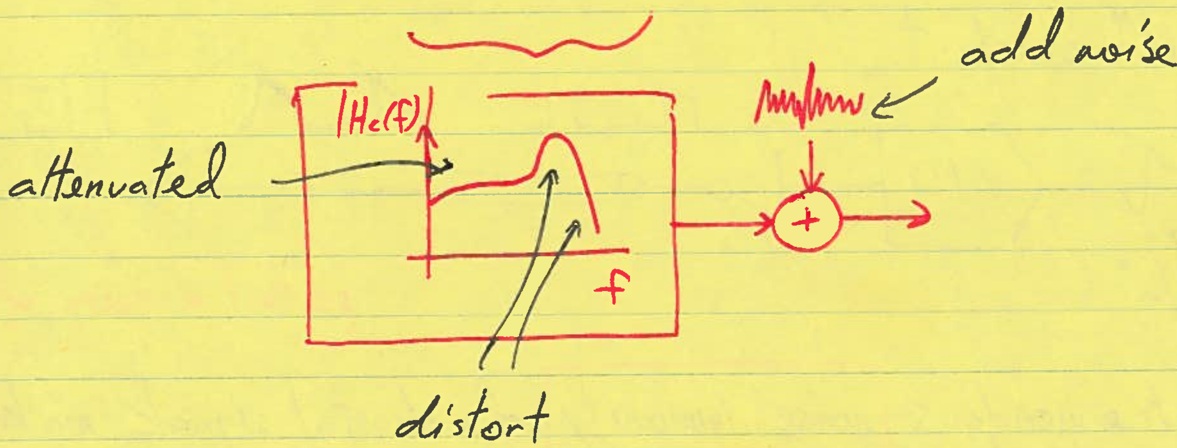


- BUT... practical digital comms. requires a sophisticated array of components

  - we will explore these requirements in this class

1.2 A Digital Comms. System



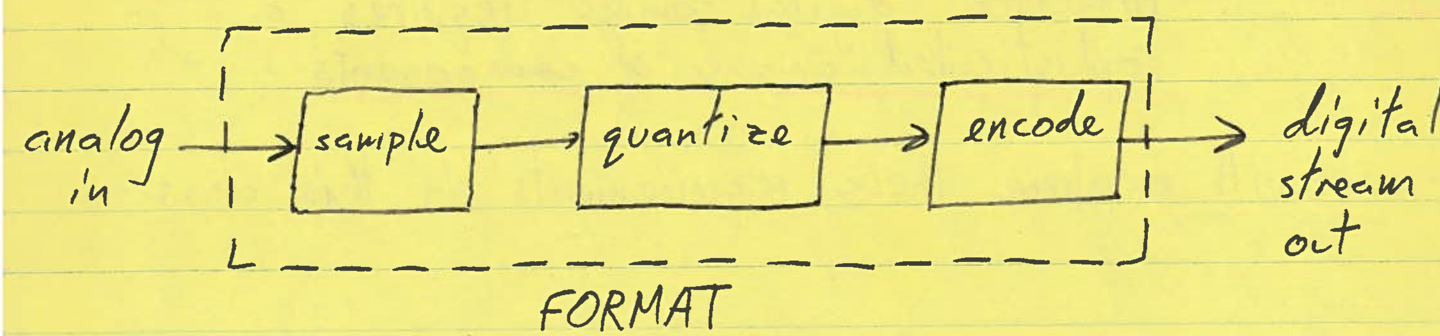


your tx & rx have to deal with all these problems

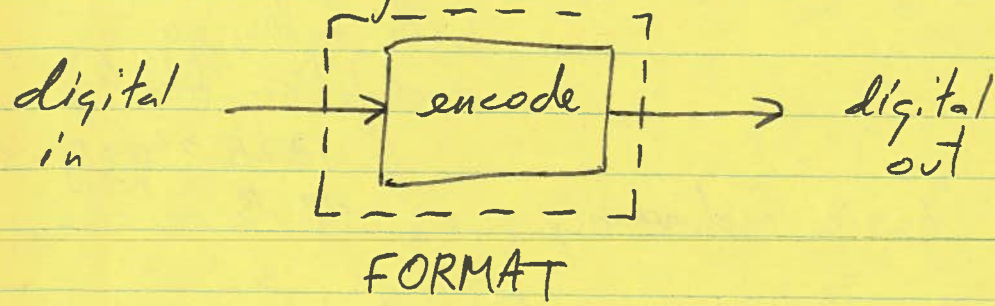
- let's take a look at some TX components

1.3 The Format

- feed digital signals into tx
- obviously needed for analog signals



- some digital can also be encoded



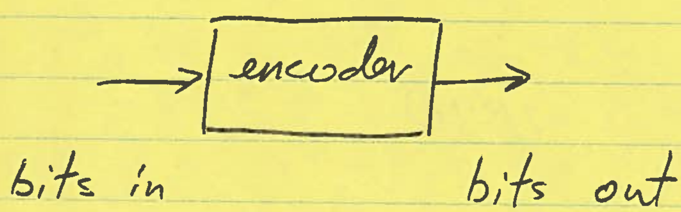
e.g. 7-bit ASCII + 1 parity or truncated to 6-bit ~~ASCII~~ (e.g. BCD)

1.4 Source Encoder & Encryption

Source Encoder → take out redundancy

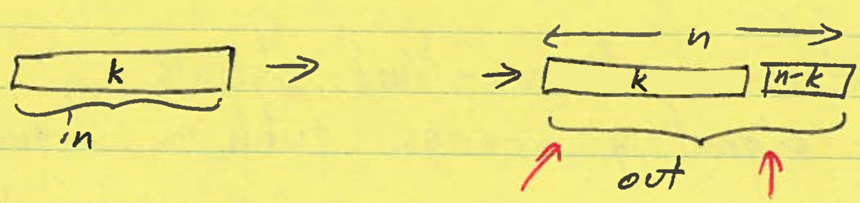
Encryption → add or scramble bits to protect secrets

1.5 Channel Encoder



- throw in more bits to increase data redundancy
- channel coding

- redundancy makes it easier to detect or correct for errors when data is distorted & noise added



use k ... to generate these n-k

- can send 2^n possible sequences
- but only 2^k are legal

- a second tier is line coding (often associcted with following modulation block)
- inlucdes very basic redundancy e.g. 4B5B

  1B2B ⇒ 0 → 01, 1 → 10
- and mapping of bits into symbol values

0		0	uniporal NRZ
1		1	

-OR-

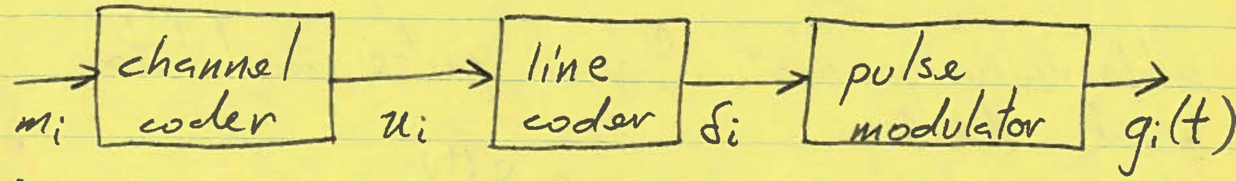
0	-1	polar NRZ
1	+1	

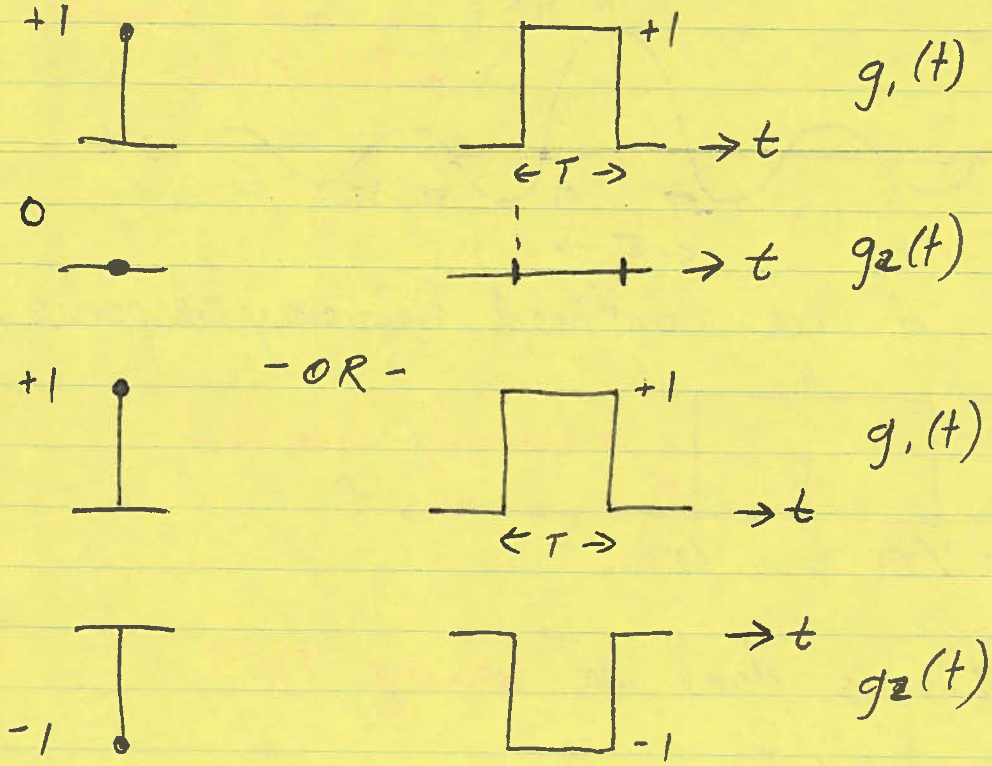
-OR-

00	-1	
01	$-1/3$	2B1Q
10	$+1/3$	
11	+1	

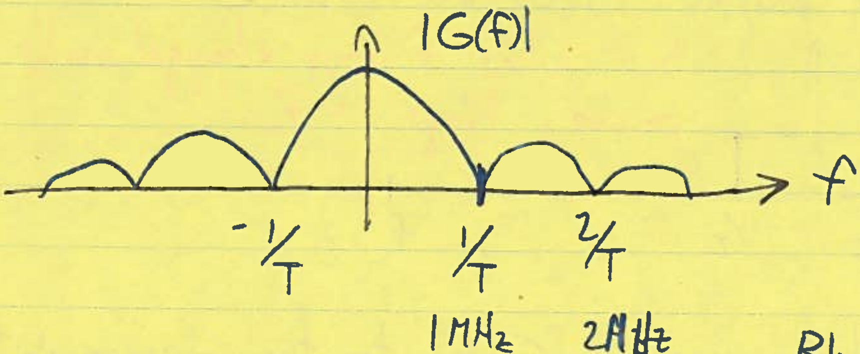
1.6 Pulse Modulation

- channels are real continuous (in time) entities
- modulators produce continuous-time signals appropriate for cignalling across such a channel





note frequency char. of such a pulse



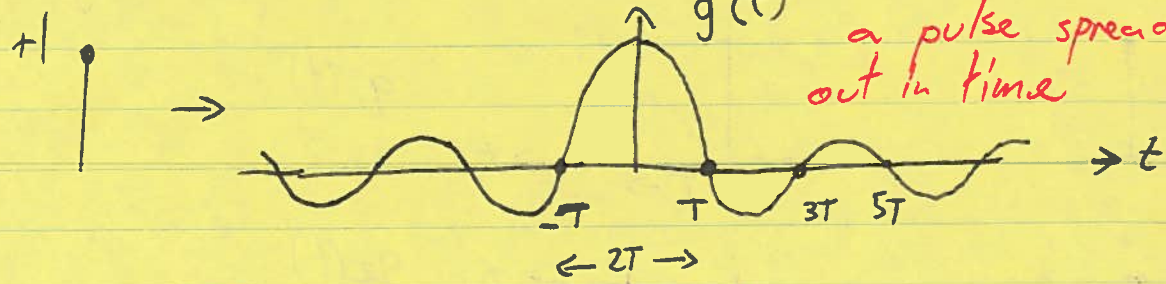
if $T = 1\mu s$

$R = \frac{1}{T} = 1 \text{Mbps}$

.. BW (W) extends to higher freqs.

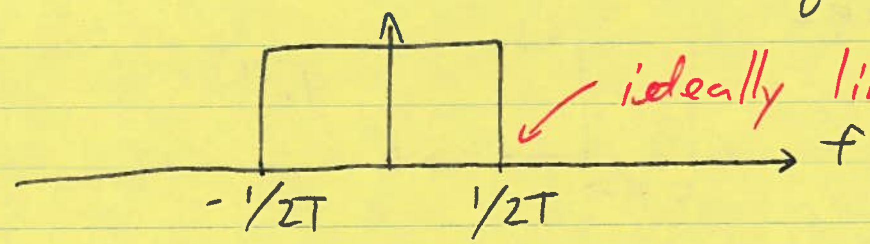
- note lots of "signal" at L.F. (progressively less as you move up)
- roughly the idea behind BASEBAND TX.

- alternatively what if your pulse modulator did this...



a pulse spread out in time

... BUT ... a nice confined frequency response

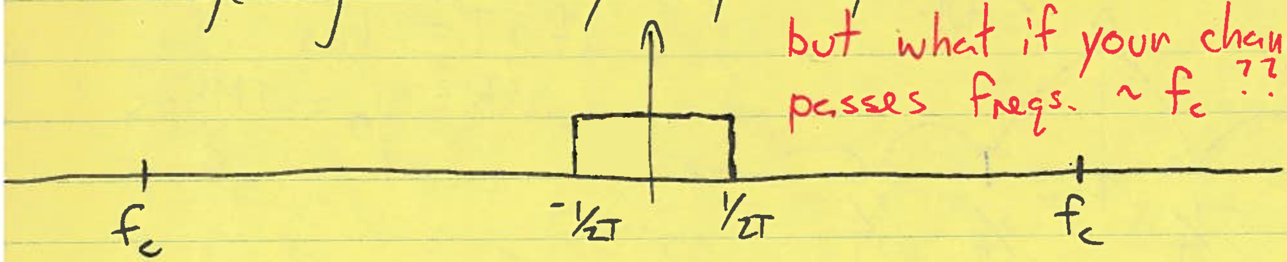


ideally limited

- turns out this is done in many DCS

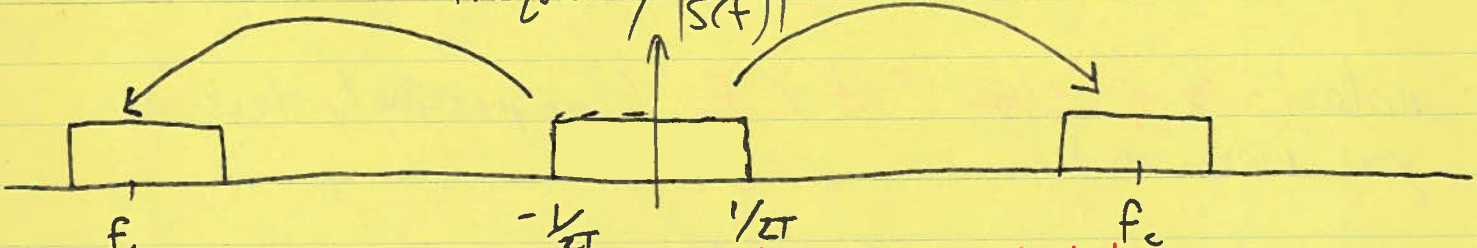
1.7 Bandpass Modulation

- getting a nicely shaped spectrum is nice

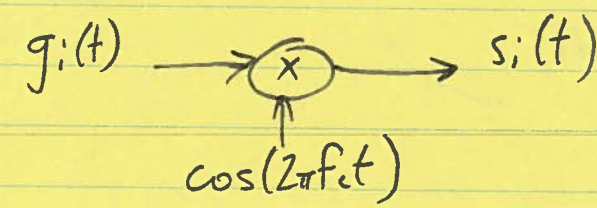


but what if your channel only passes freqs. ~ f_c ???

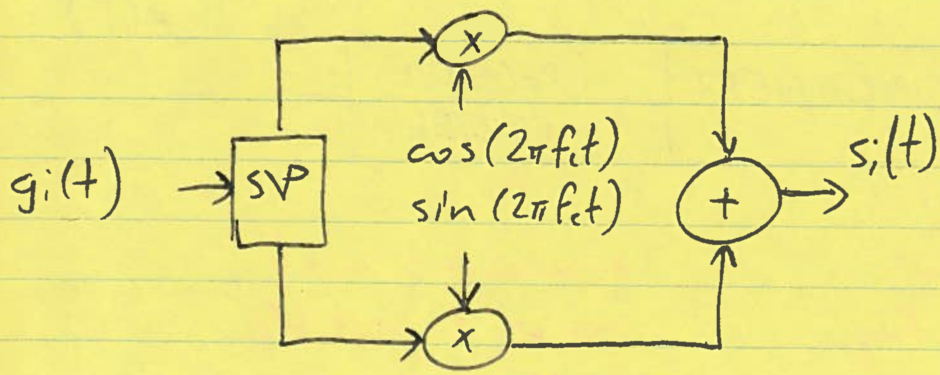
→ translate your G(f) to the appropriate frequency



→ this is called bandpass modulation

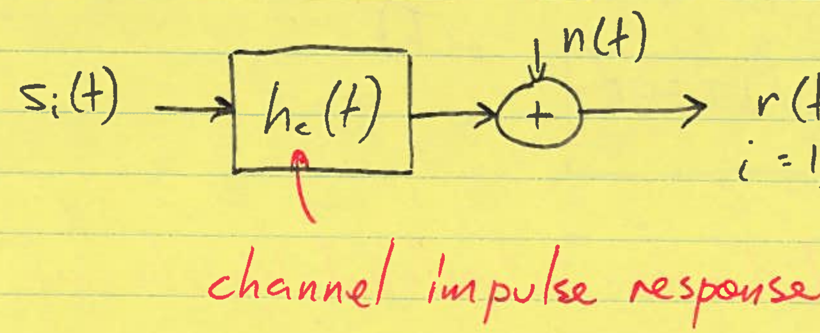


more complicatet QAM



1.8 The Channel

→ treat like a filter with additive noise

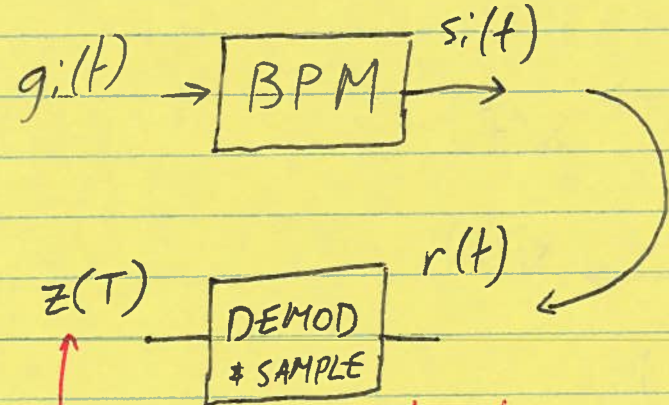


$r(t) = s_i(t) * h_c(t) + n(t)$

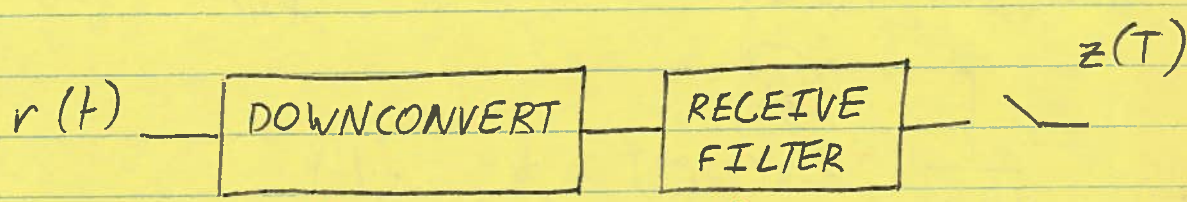
$i = 1, 2, \ldots, M$

1.9 The RX

- RX does everything in reverse & is generally harder to design (deals with small signal & random noise)

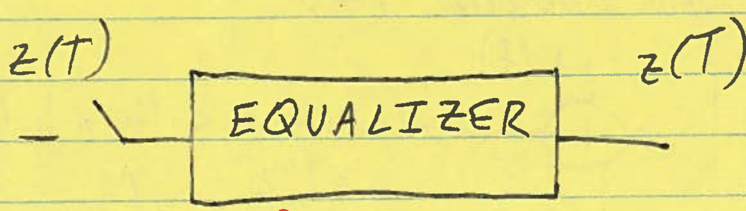


map your input signal into a single level every T



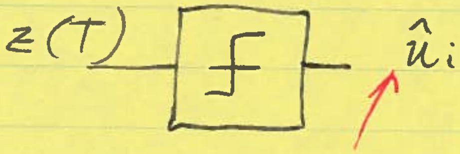
bring signal down in freq.

remove as much noise as possible in Mapping
(Matched Filter/ Correlator)



remove distortion introduced by channel

1.10 Detector



estimate of u_i

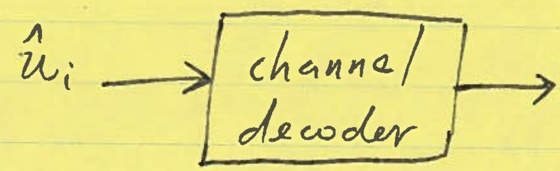
make the best possible decision on the symbol represented by $z(T)$

shooting for minimal BER or P_e

$$P_e = \frac{\#\text{ of errors}}{\text{total }\#\text{ of symbols sent}}$$

for wireless comms after detector $\sim 10^{-3} - 10^{-4}$
" wired $\sim 10^{-7} - 10^{-8}$

1.11 Channel Decoder



$P_e|_{wireless} \sim 10^{-6} - 10^{-7}$

$P_e|_{wired} \sim 10^{-12} - 10^{-20}$