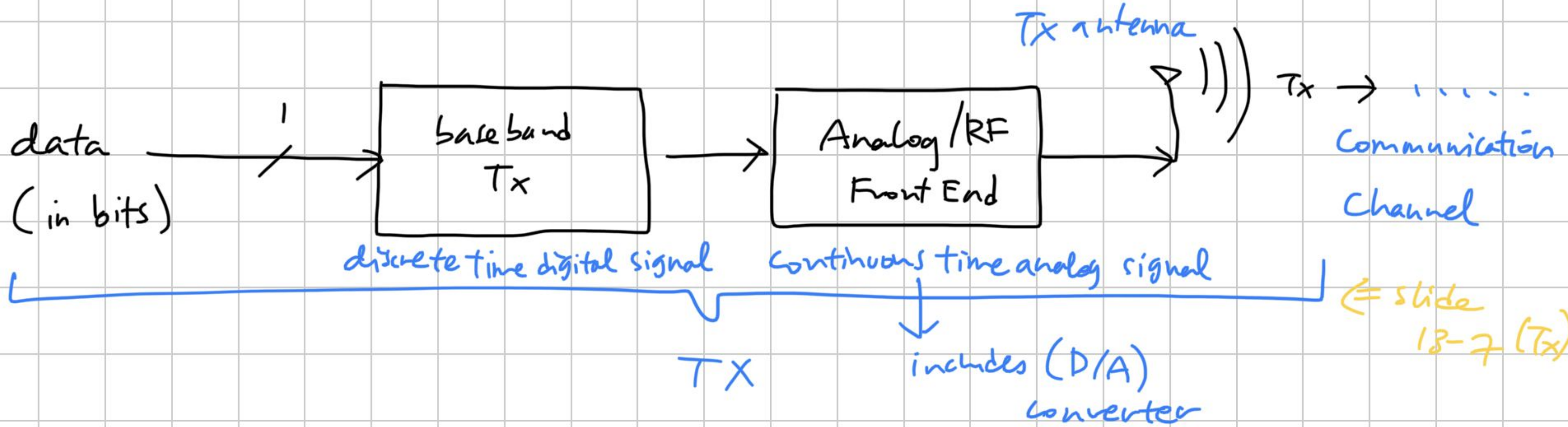
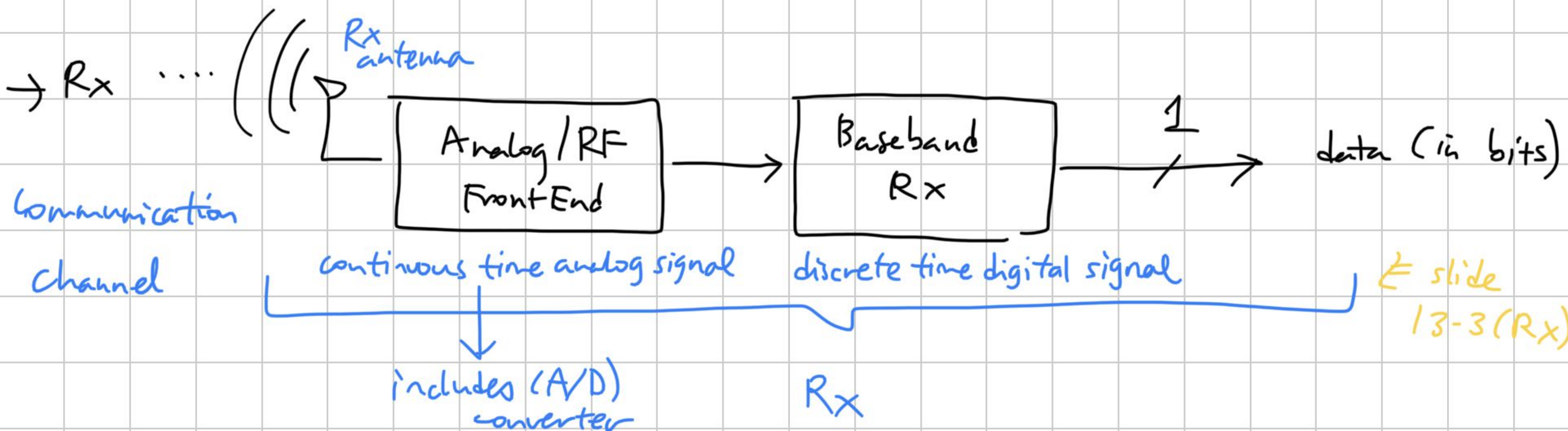
※ 03/29/2023. Wednesday DSP Lecture Digital Pulse Amplitude Modulation

PHY (Physical) Layer (aka "Modem") Block Diagram

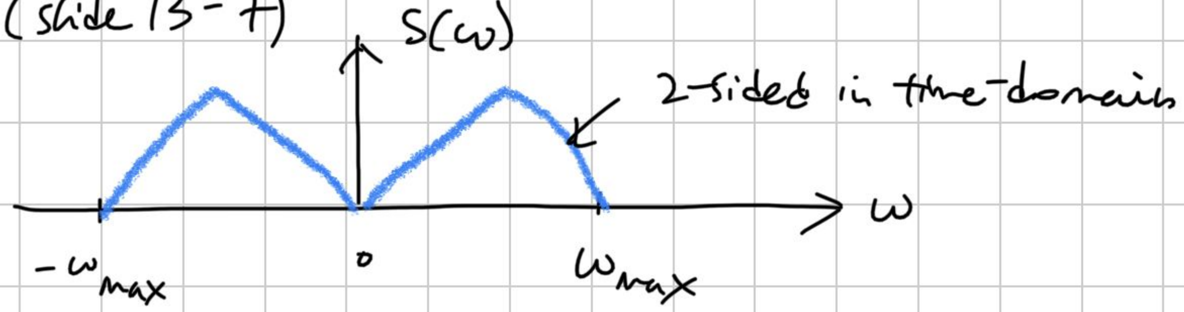




PAM Baseband (slide 13-7)

⇓

@ output of the pulseshaper



$$f_{max} = \frac{1}{2} f_{symb} (1+\alpha)$$ if pulseshaping = raised cosine pulse

$\alpha \in [0, 1]$ = roll off factor

$$\omega_{max} = 2\pi \frac{f_{max}}{f_s}$$

then modulate to higher frequency.
we get PAM Band Pass as a result.

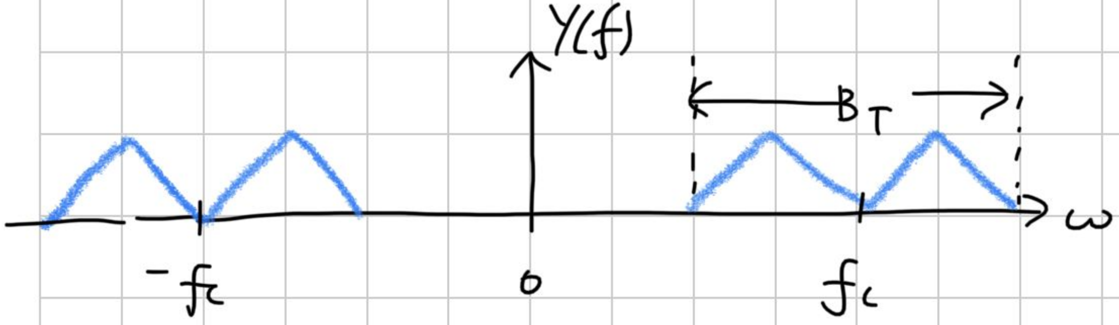
☆ you have limited amount of Bandwidth to Tx over. that is f_{symb}.

⇓

☆ the other parameter we have is the bit rate $= J f_{symb}$

J = # bits / symbol you have.

PAM Band Pass, $Y(f)$



$$B_T = 2\left(\frac{1}{2} f_{sym}\right)(1+\alpha) = f_{symb}(1+\alpha)$$

let's go back to slide 13-3:

for a voltage of $V = d$, what is it's power P? $\Rightarrow P = V^2 = d^2$

ex: so if $V = 3d$, $P = (3d)^2 = 9d^2$ (4PAM max power)

if $V = 5d$, $P = (5d)^2 = 25d^2$ (6PAM max power)

$\Rightarrow$ we see for each constellation of M-PAM,
it has a power budget. (set by regulations)

$\Rightarrow$ thus, how to select "d" s.t. ① we satisfy power budget
② can distinguish between your M symbols.

because you Tx symbols, say "d"
the communication channel adds noise (ideal scenario),
the Rx gets "d + n" (symbol + noise)

you need to select d small enough you satisfy max power budget
large enough to distinguish all M symbols
even in presence of noise

consider... you have <u>max Tx Power</u>

$(M-1)d$ max symbol amplitude (V)
$(M-1)^2 d^2$ max symbol power (W)

→ <u>for example</u>, let Max Tx Power = 16W

for 2PAM (M = 2): $(M-1)^2 d^2 \leq 16W$

$(2-1)^2 d^2 = d^2 \leq 16W$

$d \leq 4V$

for 4PAM (M = 4): $(M-1)^2 d^2 \leq 16W$

$(4-1)^2 d^2 = 3^2 d^2 = 9d^2 \leq 16W$

$d \leq \frac{4}{3} V \cong 1.33V$

then, the Rxer feedsback its Rxed SNR (signal-to-noise ratio) to the Txer based on the Txed training signal

↓

then the Txer can decide how many bits (J) to Tx.

standards tells you what settings to have on the Txer side.
- ie LTE, WiFi, cellular comms.

(break @ 11:16 AM)

(return @ 11:22 AM)

Q: how to pick bits J?

A: using Shannon Capacity Bound.

goal: maximize capacity (bits/second per Hz) thus, $J \leq \lfloor \log_2(1 + SNR) \rfloor$

└ SNR in linear units (not dB scale)

$\lfloor \cdot \rfloor$ = floors to integer.

(ie. if $\log_2(1+SNR) = 2.5$

then $J = \lfloor 2.5 \rfloor = 2$)

Polyphase Filter Bank vs Upsampling & Interpolation Filter
(Slide 13-16)

Direct Structure

→ provides savings on roughly a factor of L in terms of computations & Memory Size

walkthrough / explanation of Polyphase Filter bank example compared to Direct Structure
(highly recommended to rewatch lecture @ 11:30 AM)

Polyphase Filter bank does the EXACT SAME result as the Direct Structure but it removes all multiplications by 0

⇒ thus, the polyphase filters can operate at a lower frequency (f_{symb})

but the Direct Structure must operate at the upsampled frequency ($2f_{symb}$)

Polyphase filter bank gives us massive savings in terms of implementation / computational complexity, but does the exact same calculation as the Direct structure!

⇒ thus, we like to always use Polyphase Filters

how else could we improve speed?

⇒ parallel computation in hardware (ie. using FPGA)