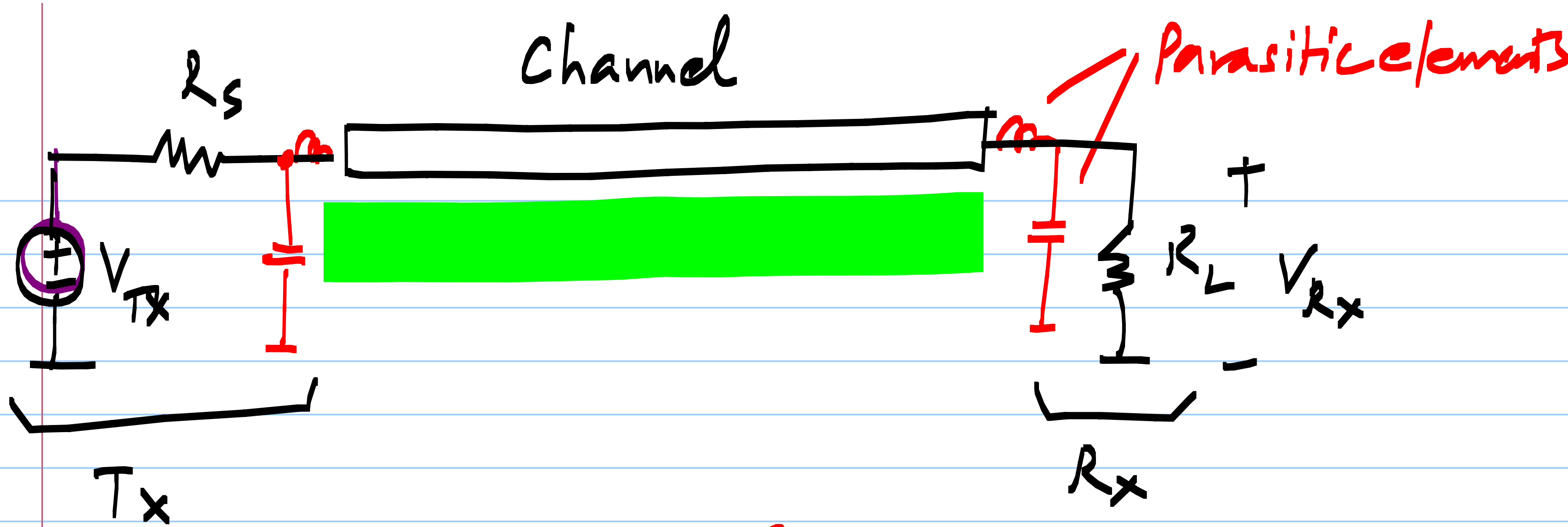
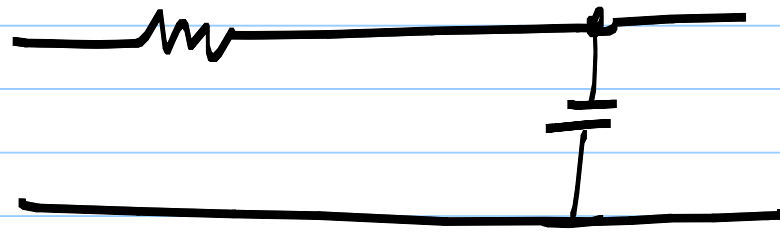
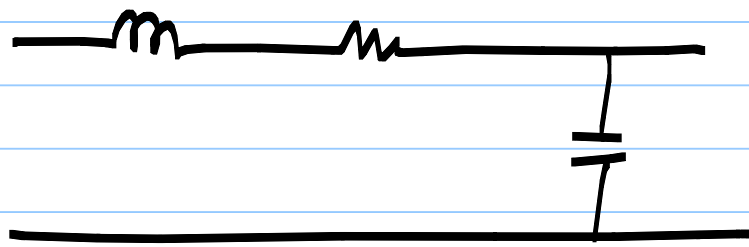


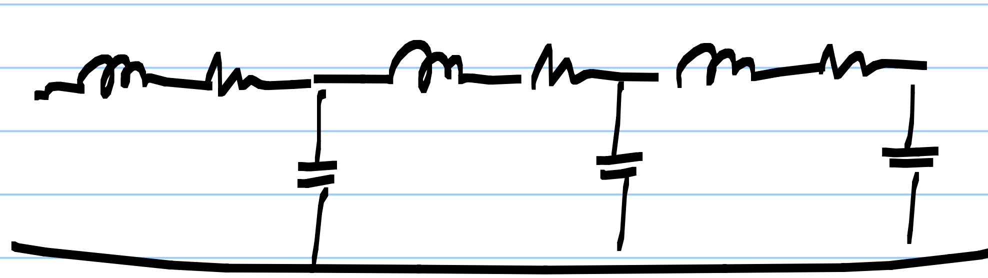
1. Impedance mismatch (+ parasitic elements)
2. Transmission line losses $\left(\frac{L_0}{R_0} \neq \frac{C_0}{G_0}\right)$
   - skin effect
   - dielectric losses



Lumped R C

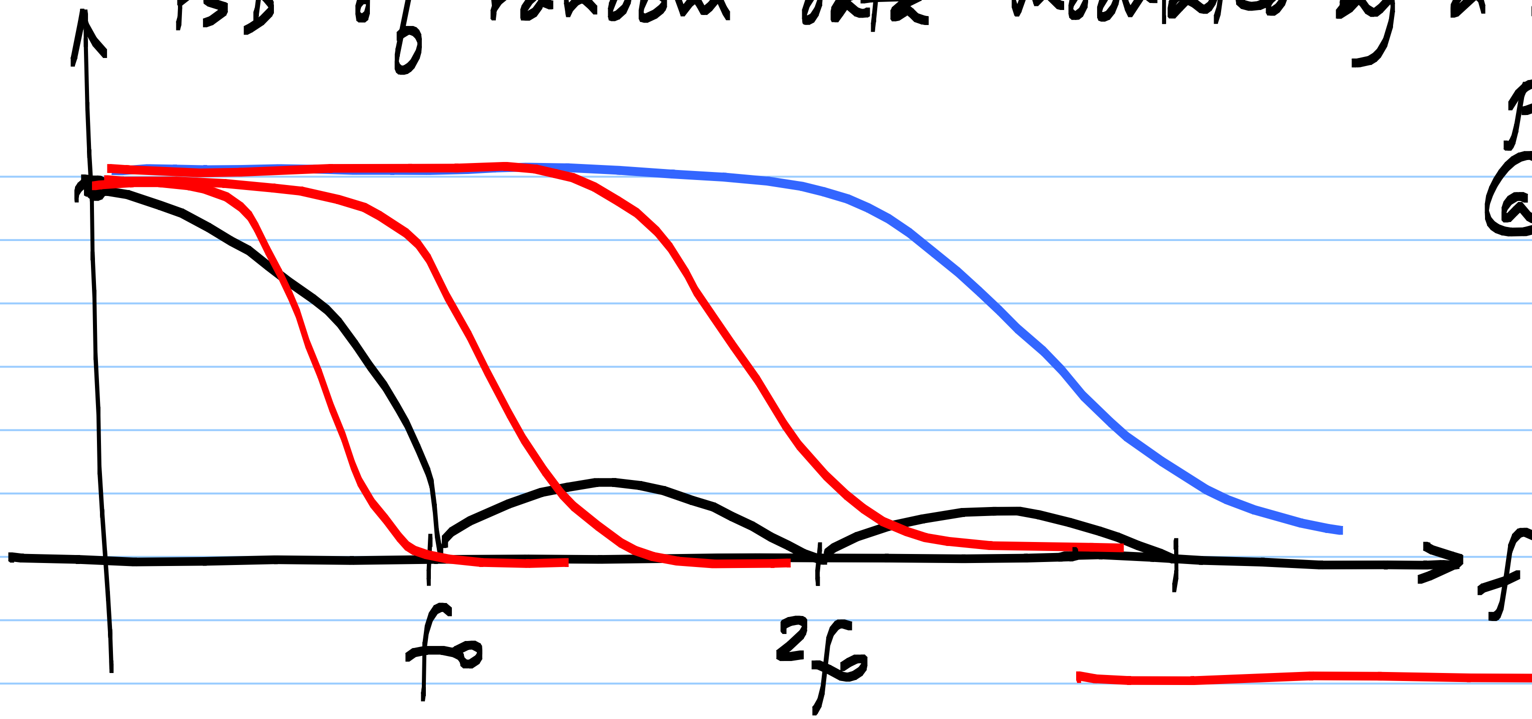


Lumped R, L, C

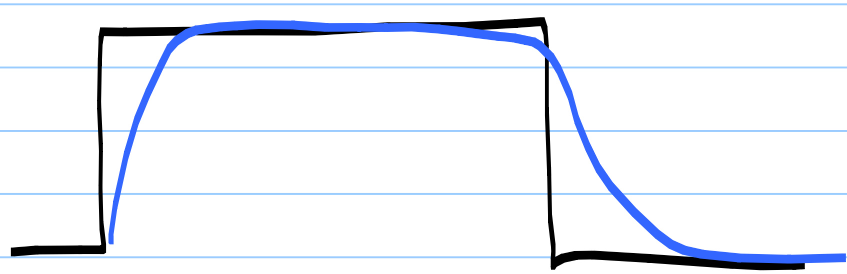


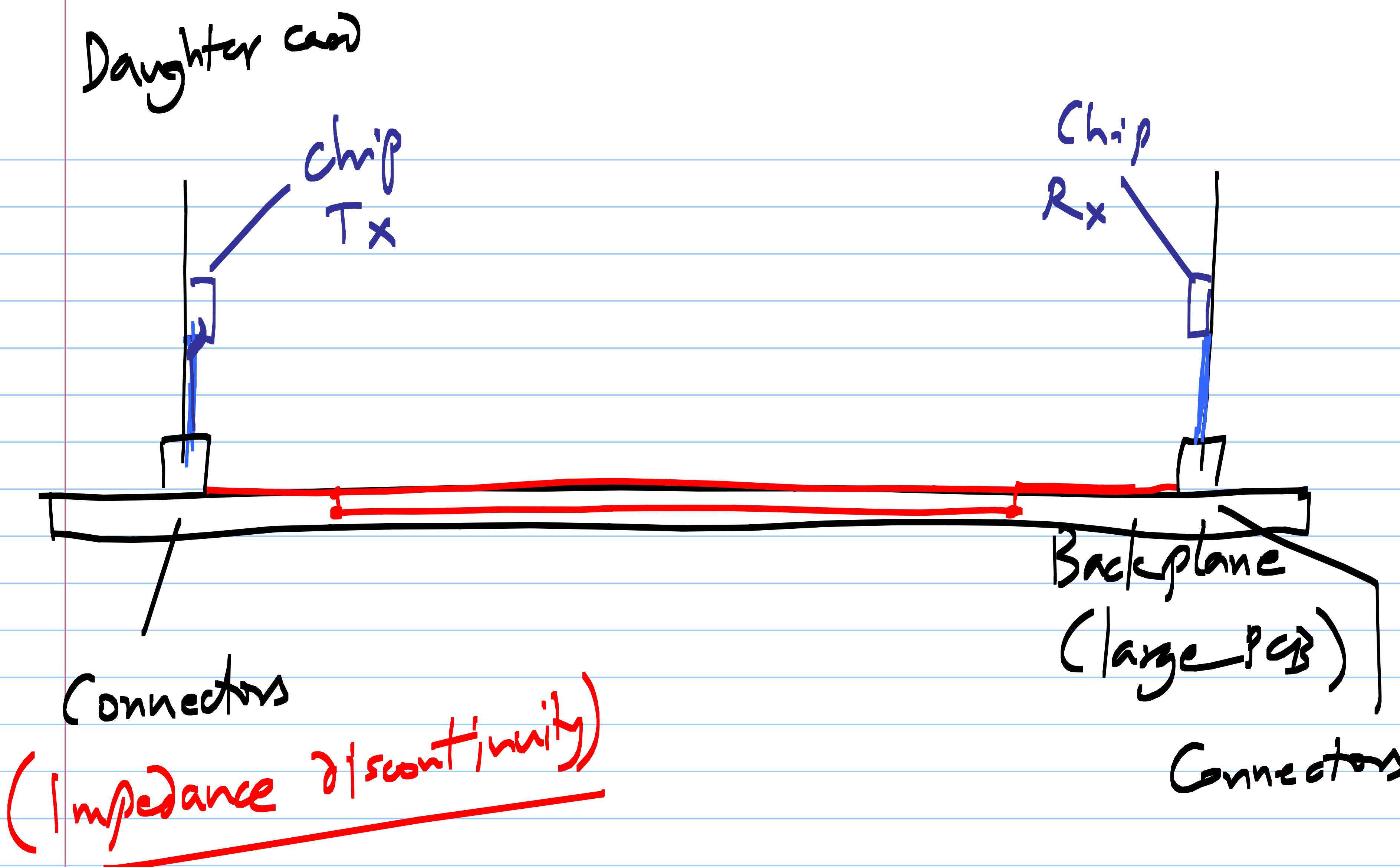
Distributed
R, L, C

PSD of random data modulated by a rectangular pulse @ f_0

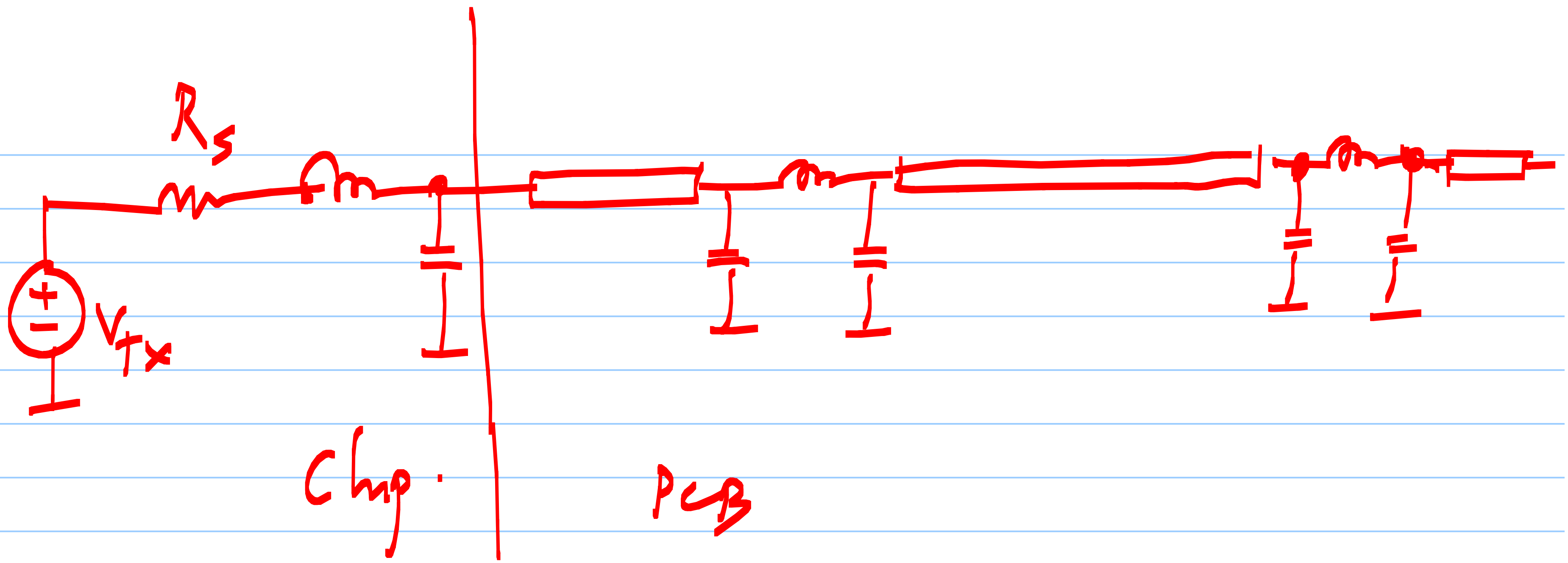


3dB BW > $0.75 f_0$

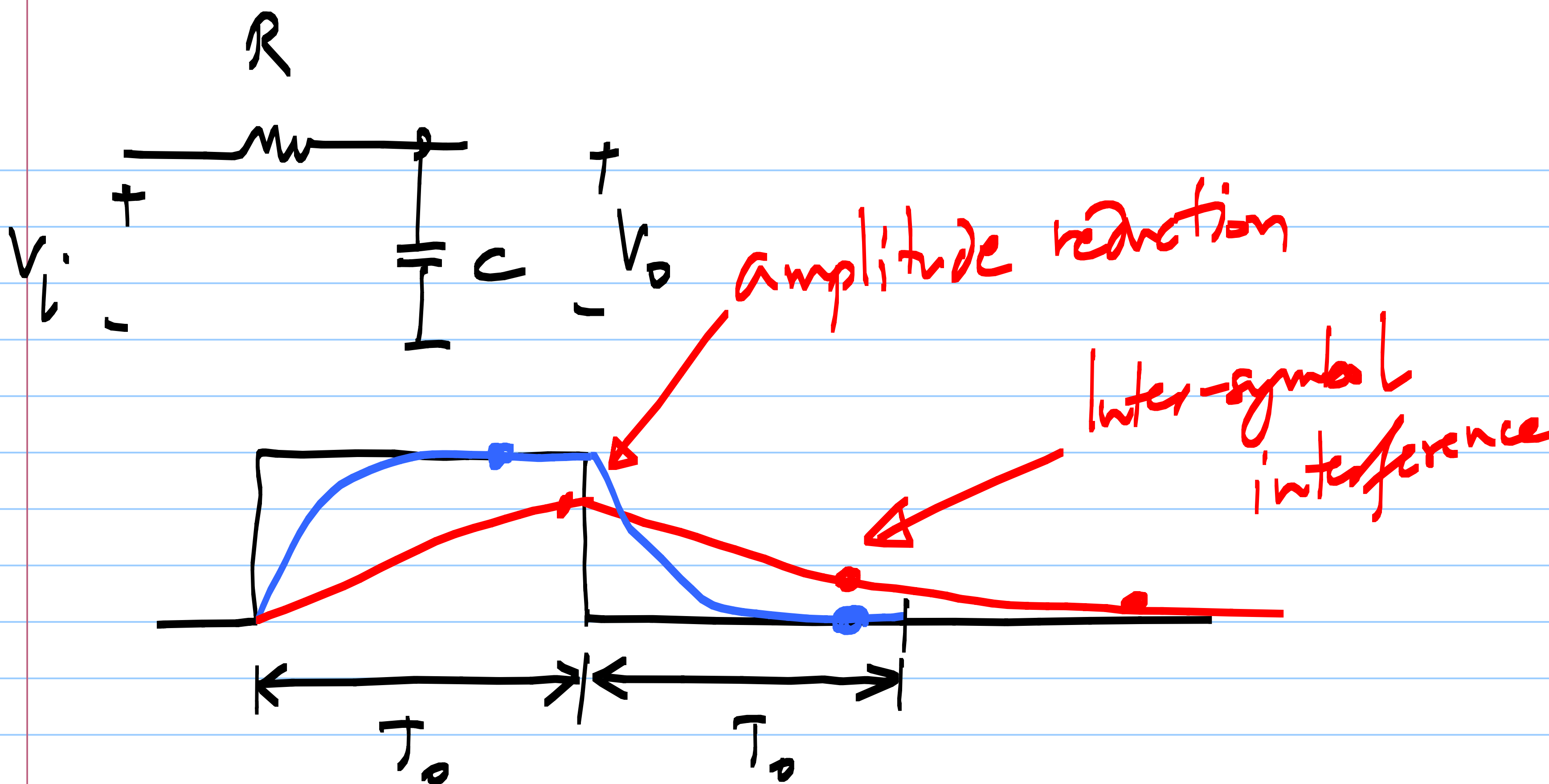




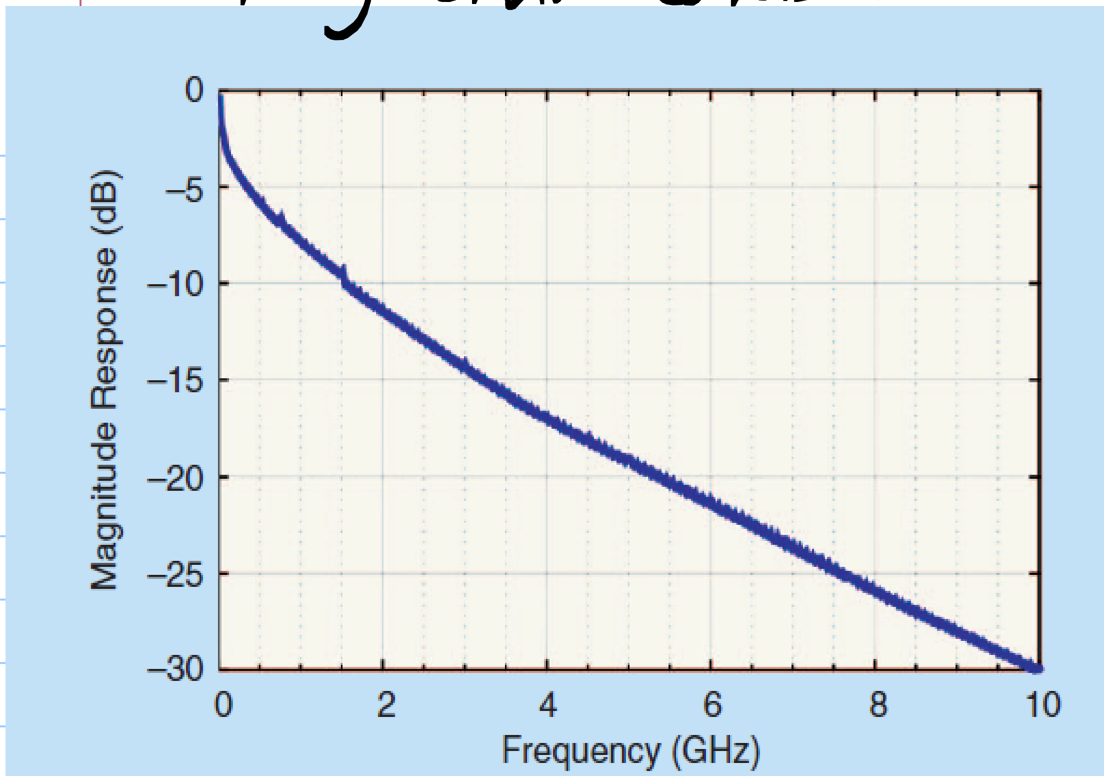
Daughter card
chip Tx
Chip Rx
Backplane (large PCB)
Connectors
(Impedance discontinuity)
Connectors



Rs
Vtx
Chip.
PCB


R
+
-
Vi
C
+
-
Vo
amplitude reduction
Inter-symbol interference
To
To

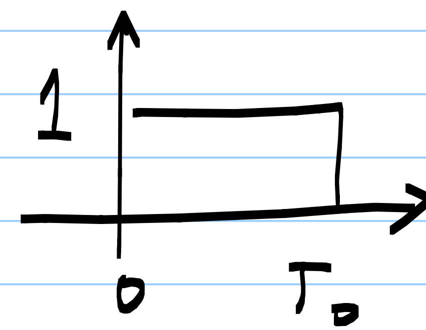
Tony Chan Carusone in the IEEE SSCS Magazine

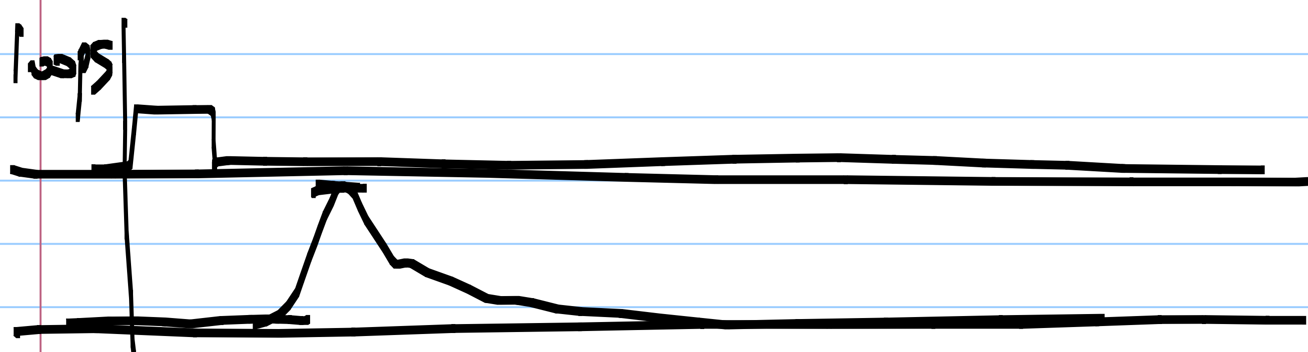


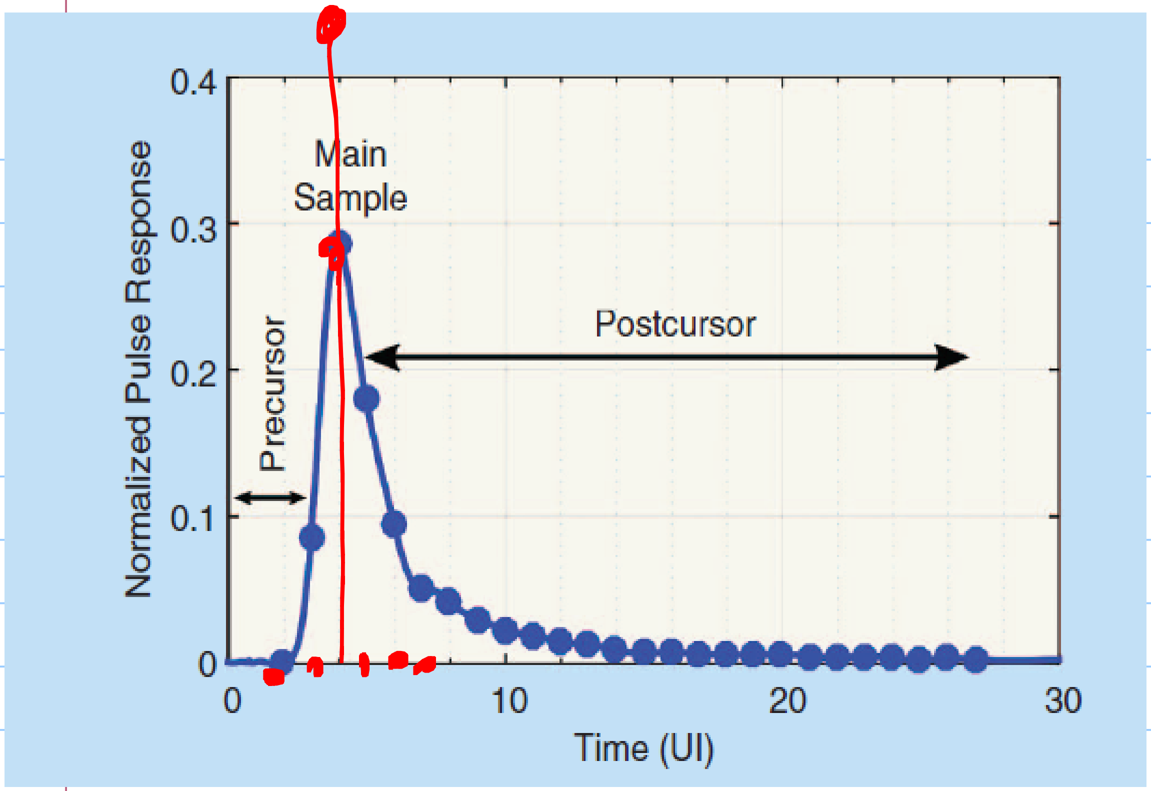
$\{a_k\}$ ± 1

$$\sum_k a_k p(t-kT)$$

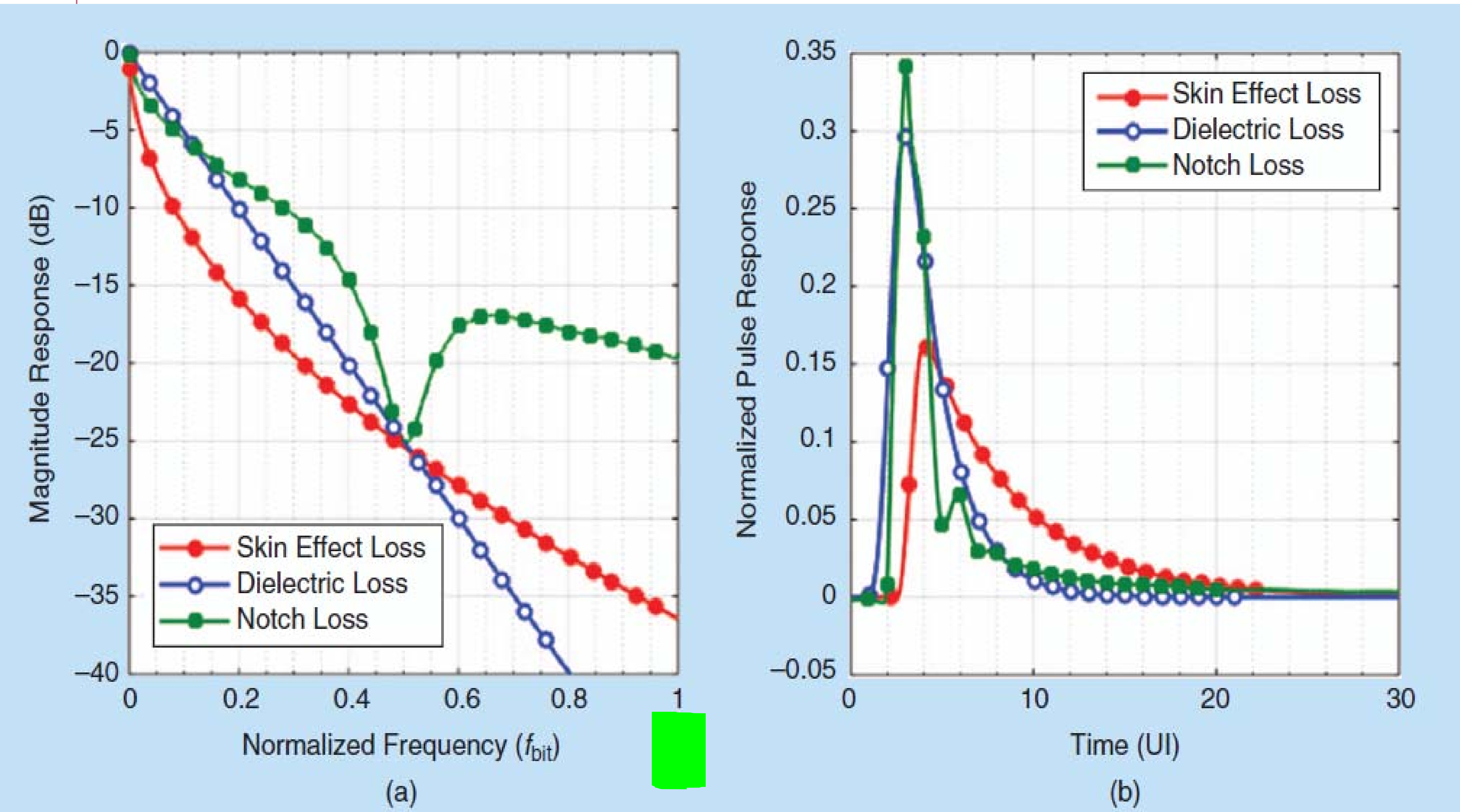
$p(t)$:



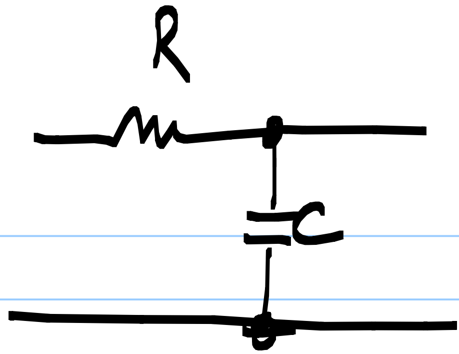


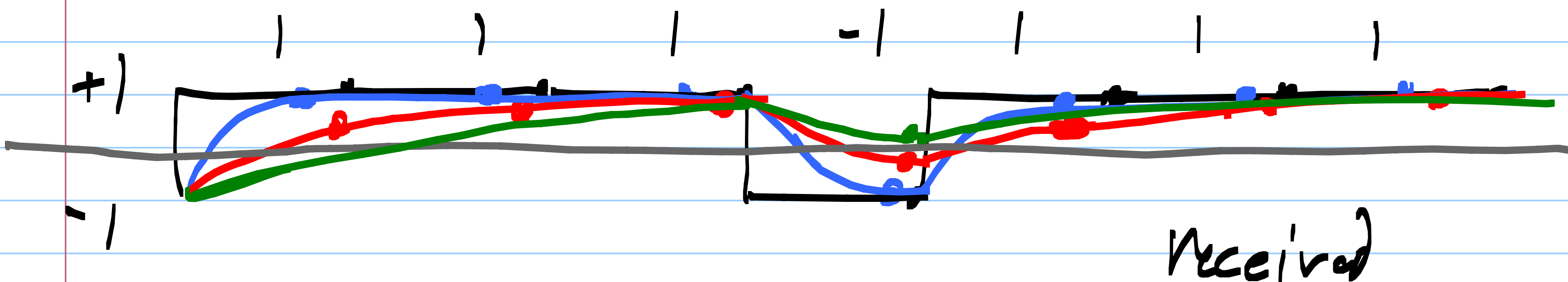


Normalized Pulse Response
0.4
0.3
0.2
0.1
0
Main
Sample
Precursor
Postcursor
0
10
20
30
Time (UI)

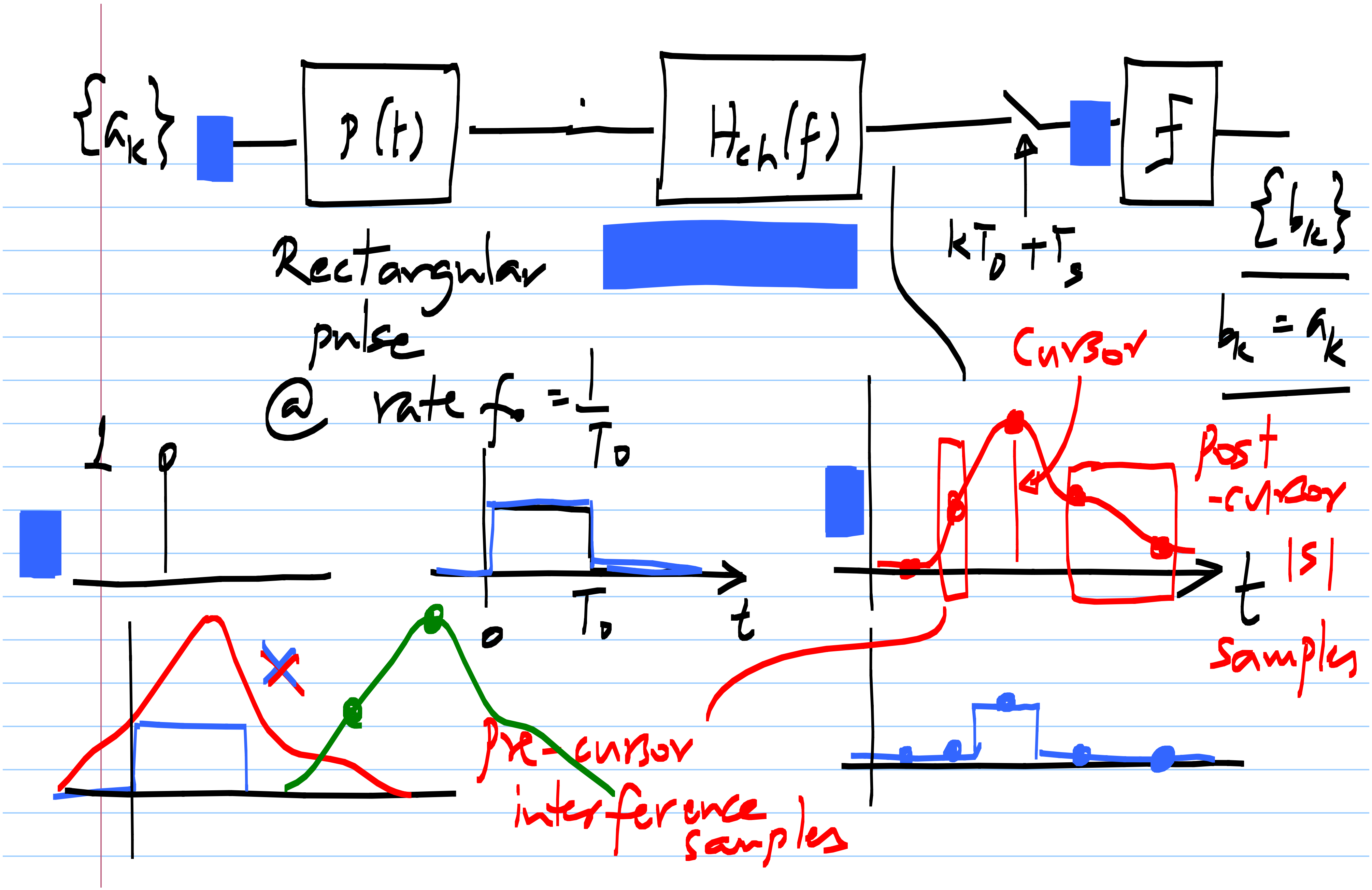


0
−5
−10
−15
−20
−25
−30
−35
−40
Magnitude Response (dB)
0
0.2
0.4
0.6
0.8
1
Normalized Frequency (f_{bit})
Skin Effect Loss
Dielectric Loss
Notch Loss
(a)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
−0.05
Normalized Pulse Response
0
10
20
30
Time (UI)
Skin Effect Loss
Dielectric Loss
Notch Loss
(b)



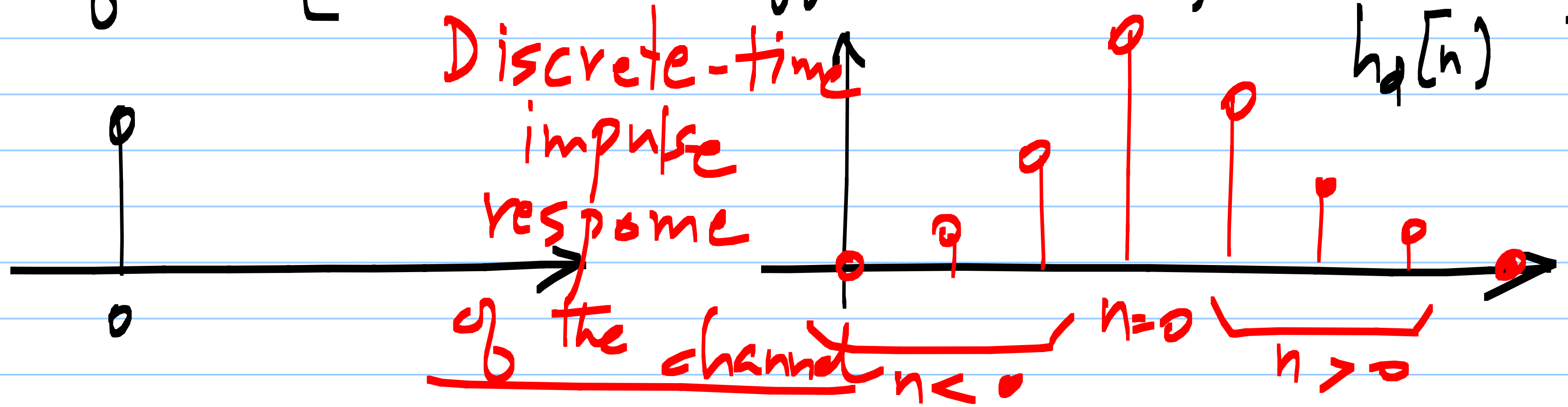


Intersymbol interference: The value detected in a symbol interval depends on transmitted values at other symbol intervals.


{a_k}
p(t)
H_ch(f)
kT_0 + T_s
{b_k}
b_k = a_k
Rectangular pulse @ rate f_0 = 1/T_0
1
0
T_0
t
Cursor
Post-cursor
ISI
t
samples
Pre-cursor interference samples

Discrete-time channel model

- A single "1" through the pulse shaper and the channel
- Sample the channel output at intervals of T_0 [with an offset to sample the peak]



$$x[n] = a_n$$

$$y[n] = x[n] * h_d[n]$$

$$= \sum_k x[n-k] \cdot h_d[k]$$

$$y[0] = x[0] \cdot h[0] + x[1] \cdot h[-1]$$

$$+ x[-1] \cdot h[1]$$

$$+ x[-2] \cdot h(2) \cdots$$

$$\vdots$$

~~Ideally~~ $h_d[n] = \delta[n]$ general $h_d[n]$

If $x[n] = +1$, $y[n] > 0 \Rightarrow$ No BER

$$\left\{ y[n] = \sum_{k} x[n-k]\, h[k] \right.$$

If $x[n] = +1$, what is the worst case $y[n]$ (smallest)

$$y[n] = \sum_{k} x[n-k]\, h[k]$$

~~h[o~~

$$= \underbrace{\underbrace{x[n]}_{+1} \cdot h[0]}_{\text{Cursor}} + \overbrace{\underbrace{\sum_{k \neq 0} x[n-k]\, h[k]}_{|S| \text{ terms}}}$$

$\overline{\underline{h[0] > 0}}$

$$= \overset{0.4}{h[0]} - \underbrace{\overset{0.6}{\sum_{k \neq 0}} |h[k]|}_{\text{Worst case } |S|}$$