# Baseband Comm.

Part 2

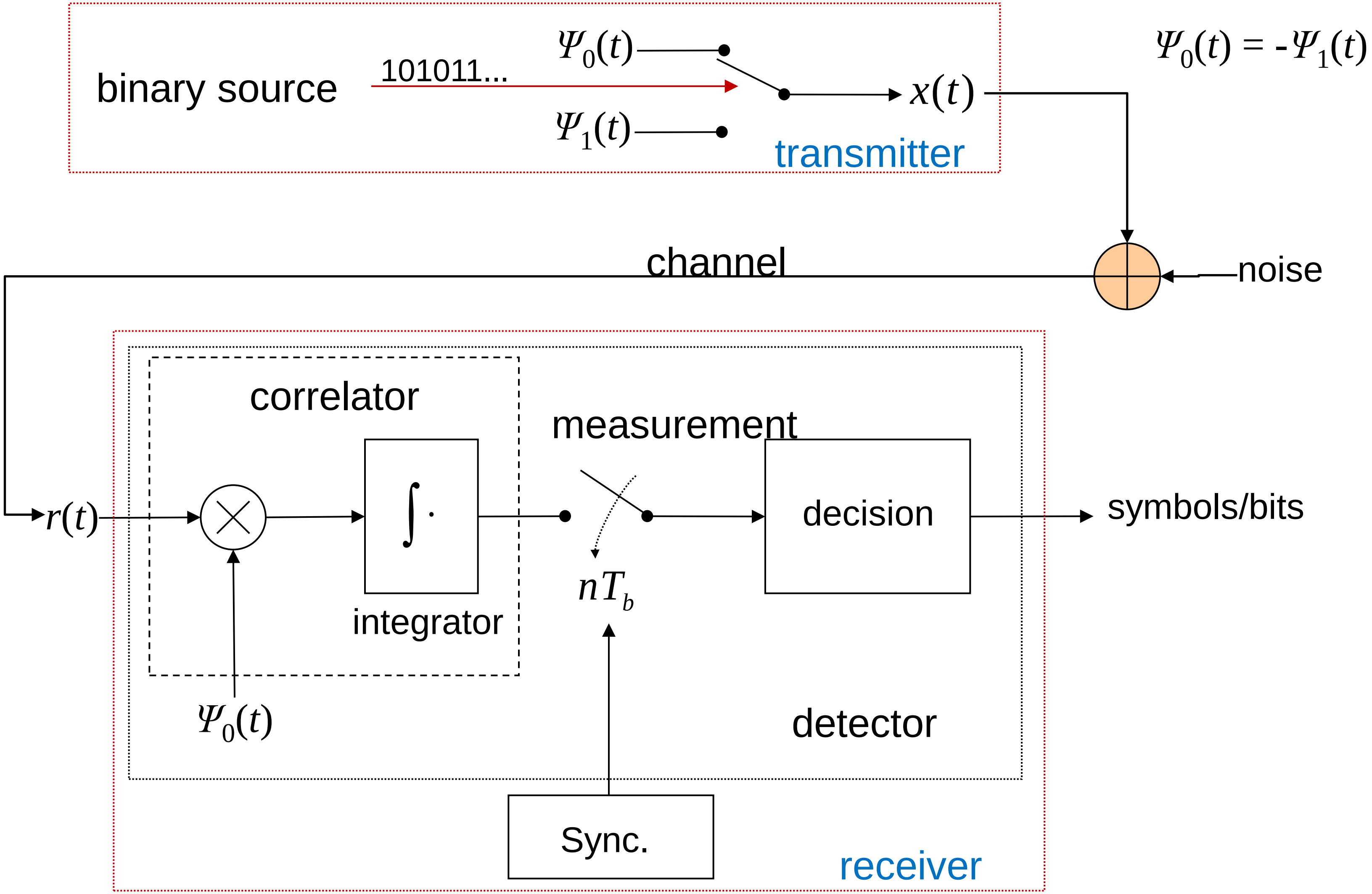
by Erol Seke

For the course "**Communications**"

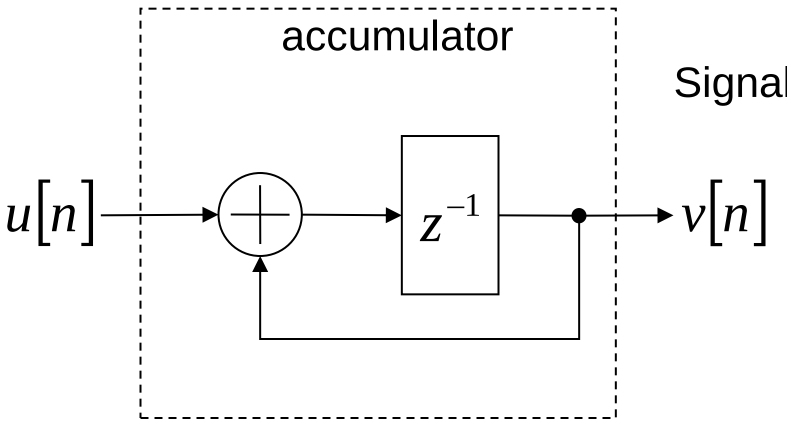
ESKİŞEHİR OSMANGAZİ UNIVERSITY

# Summary

Remember the conceptual binary antipodal transmitter/receiver (Tx/Rx) schema

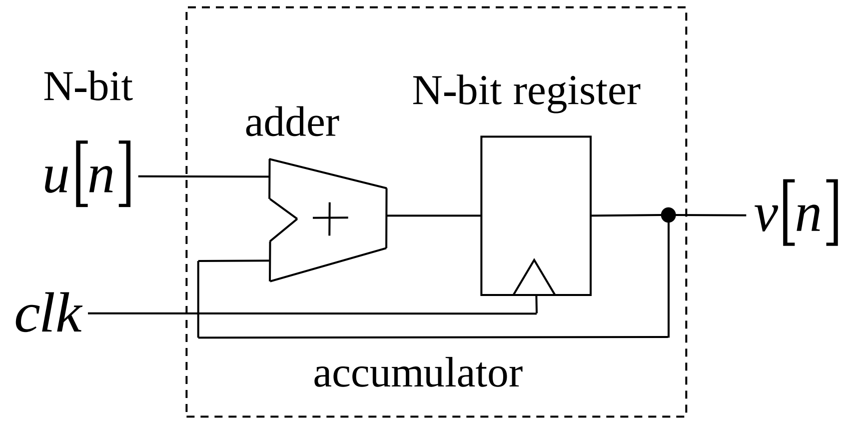


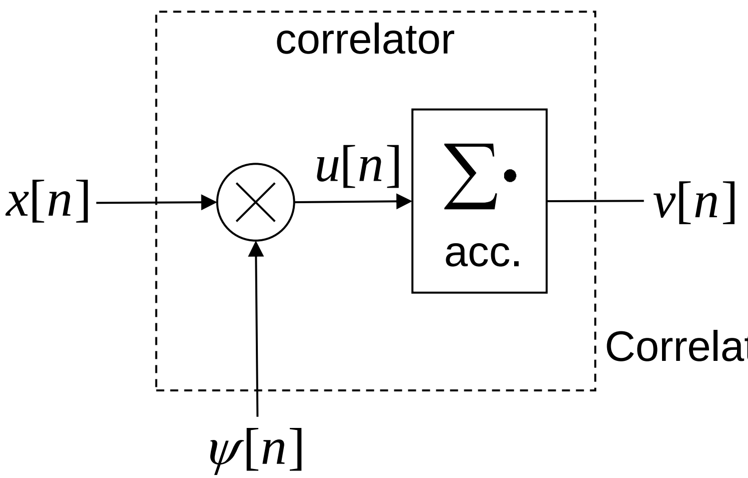
# Digital Integrator/Correlator




Signal processing symbols

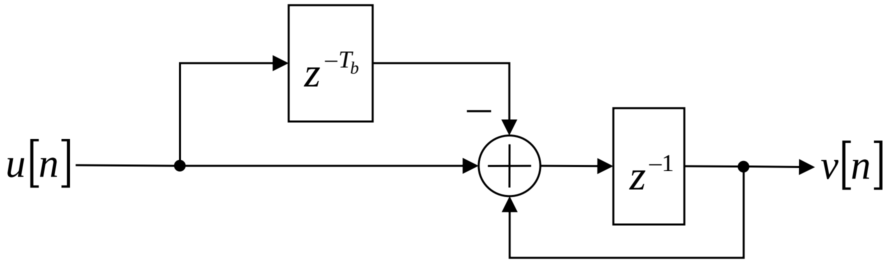
Digital Circuit for $\sum \bullet$

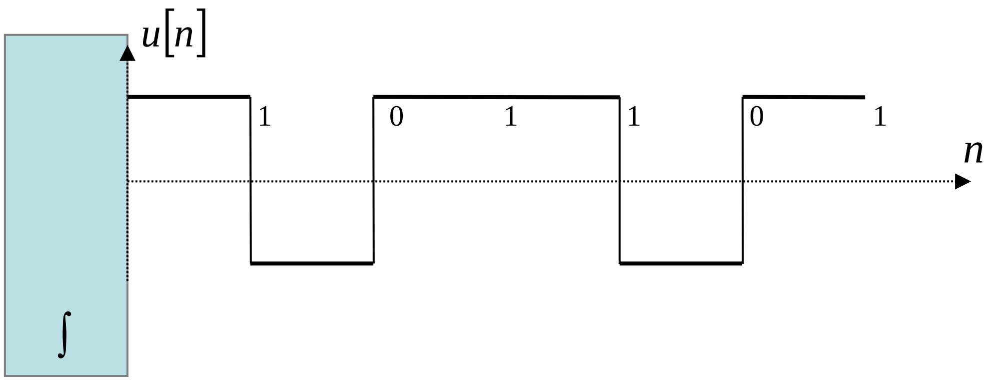


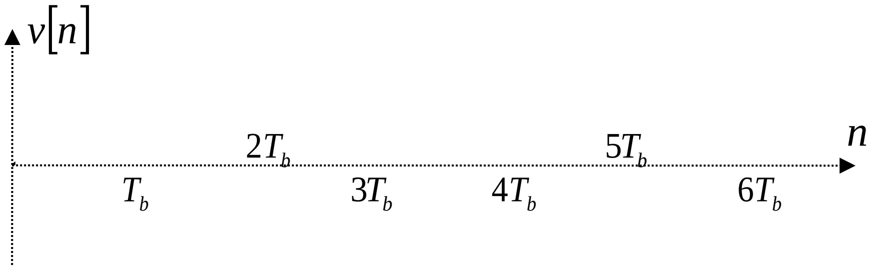




Correlator circuit

# Output of $[0, T_b]$ Correlator

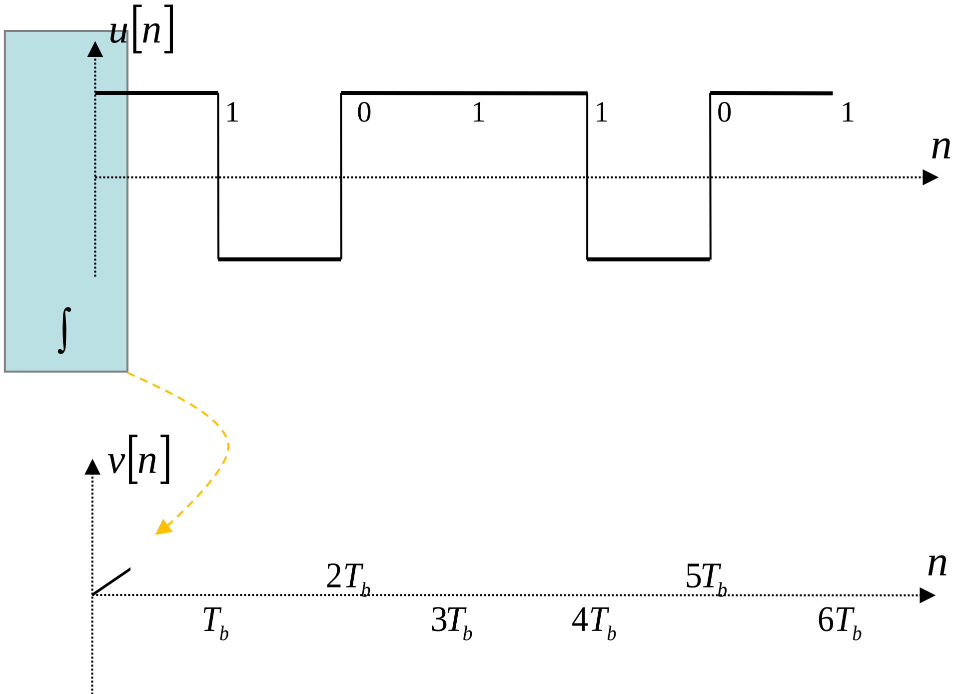



measurement and decision instants : $nT_b$

# Output of [0,$T_b$] Correlator



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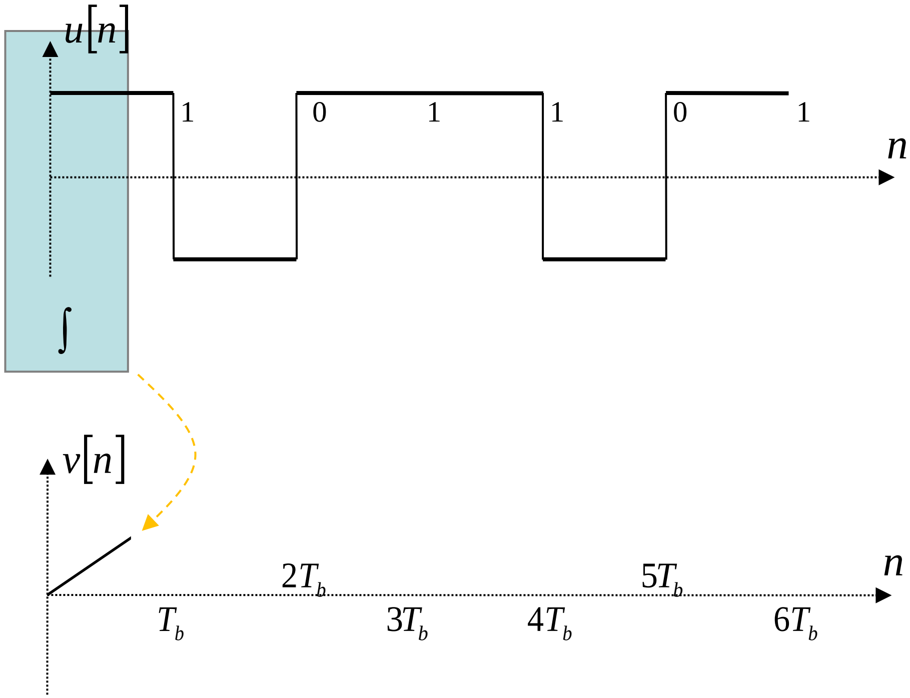
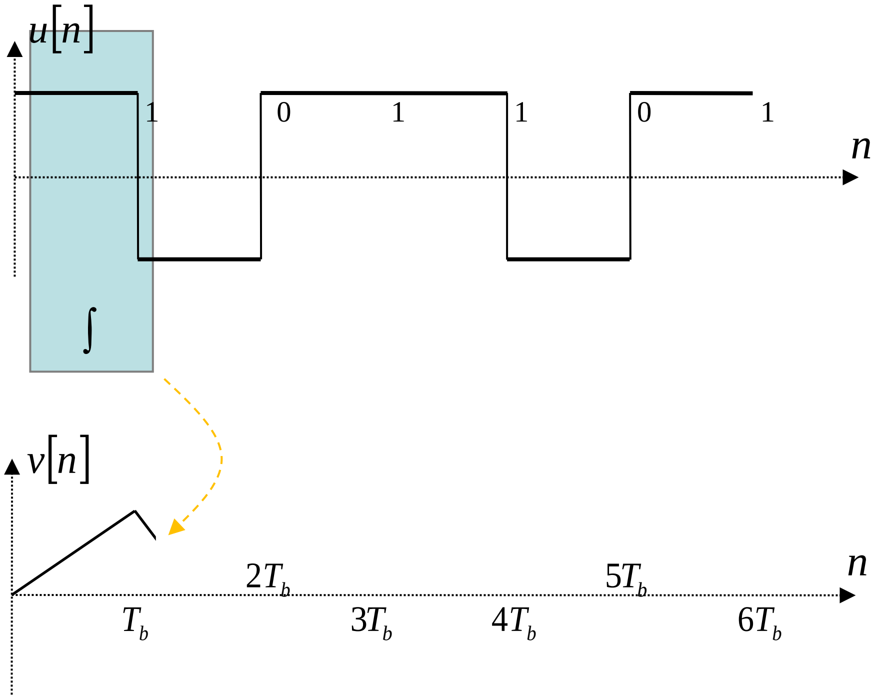
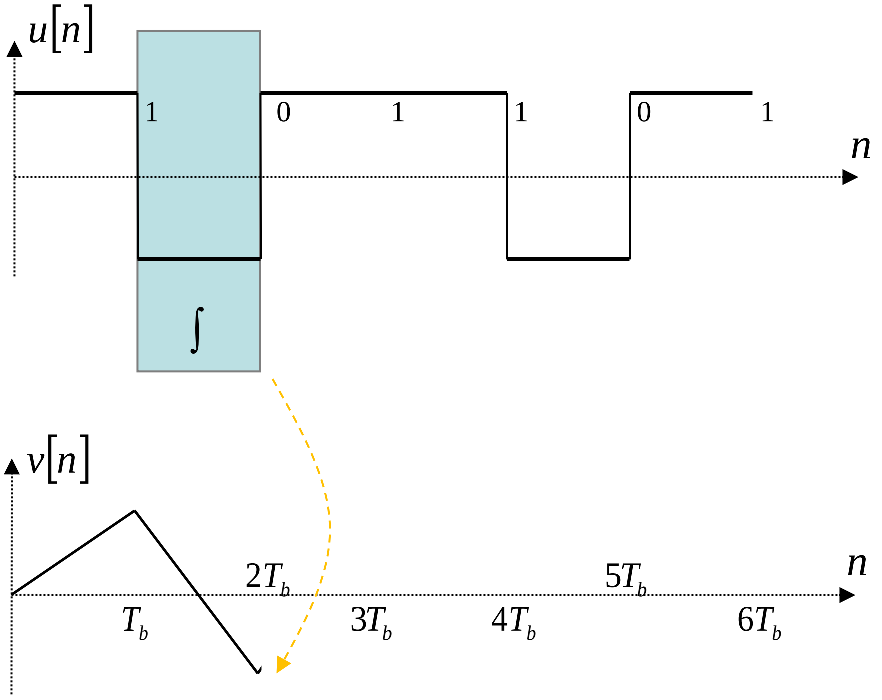


# Output of [0,$T_b$] Correlator



# Output of [0,$T_b$] Correlator



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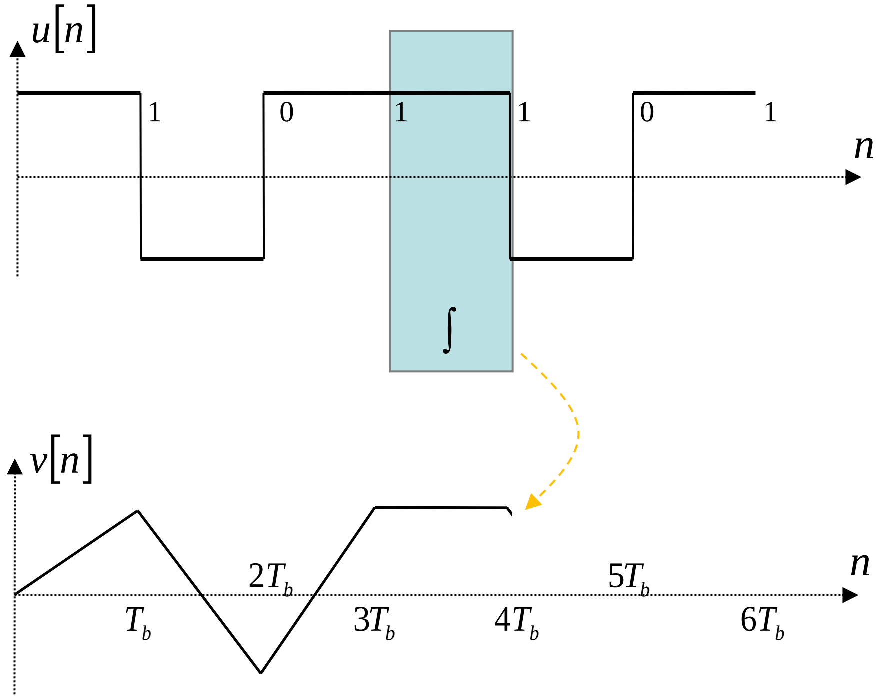
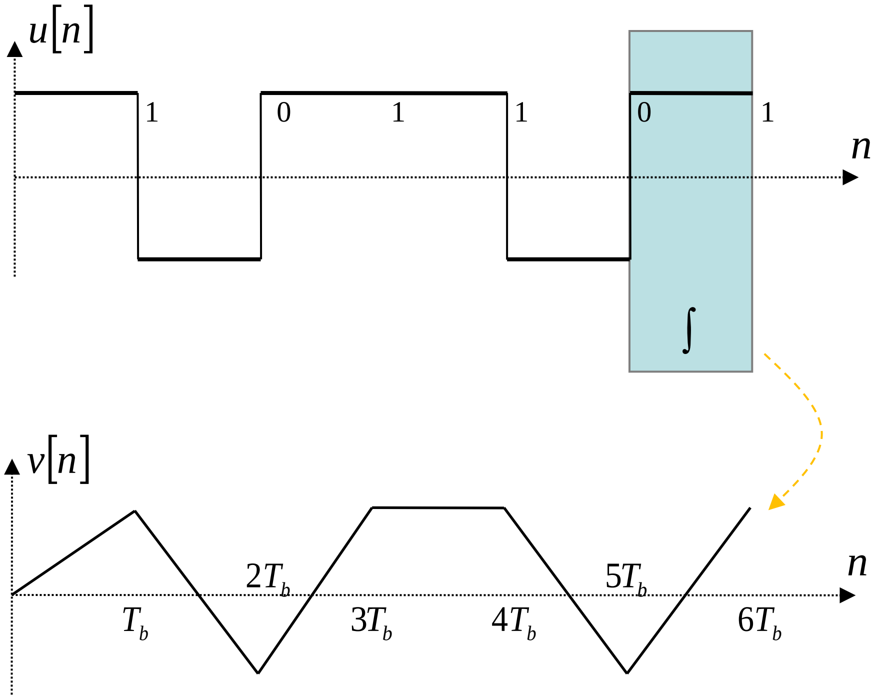
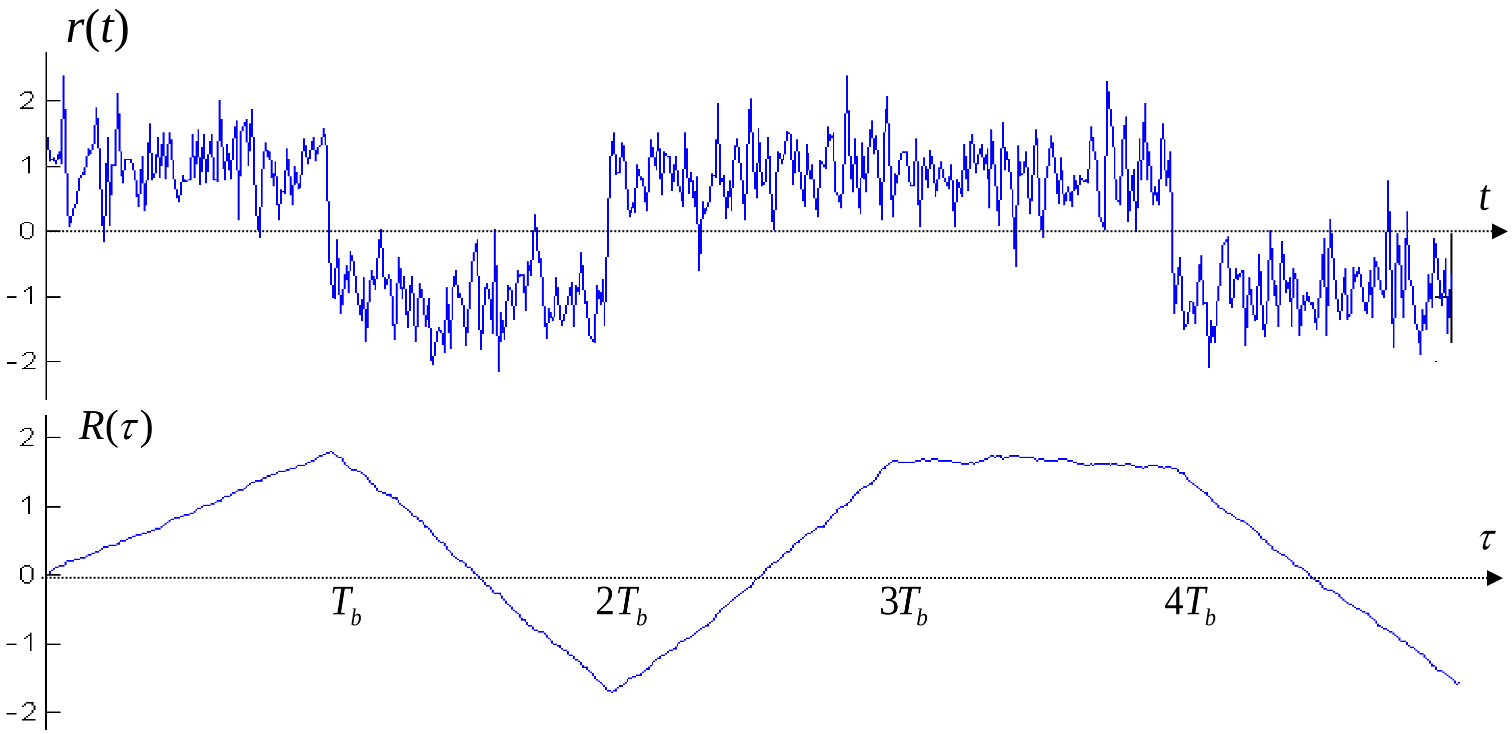


# Output of [0,$T_b$] Correlator

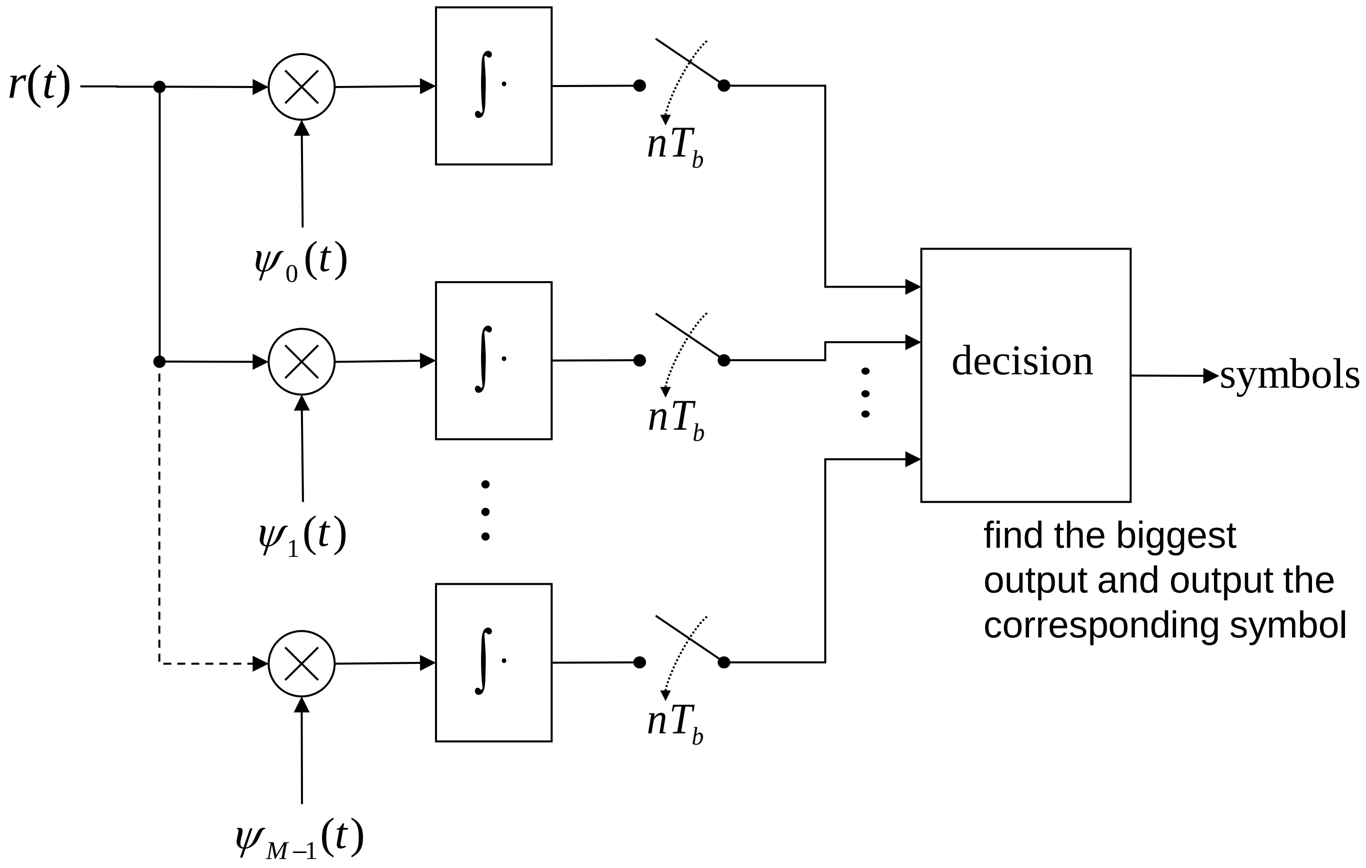


# Output of [0,$T_b$] Correlator for Noisy Input




measurement and decision instants : $nT_b$

# M-ary Correlator Receiver



# Corrolary

1. If M=2, then use antipodal waveforms
2. If M=4, then use antipodal and orthogonal waveforms

   $\Psi_0(t)$ and $\Psi_1(t)$ are antipodal

   $\Psi_2(t)$ and $\Psi_3(t)$ are antipodal

   These two sets are orthogonal to each other

3. If M>4, then try to use as much antipodal and orthogonal pairs as you can

Reason:

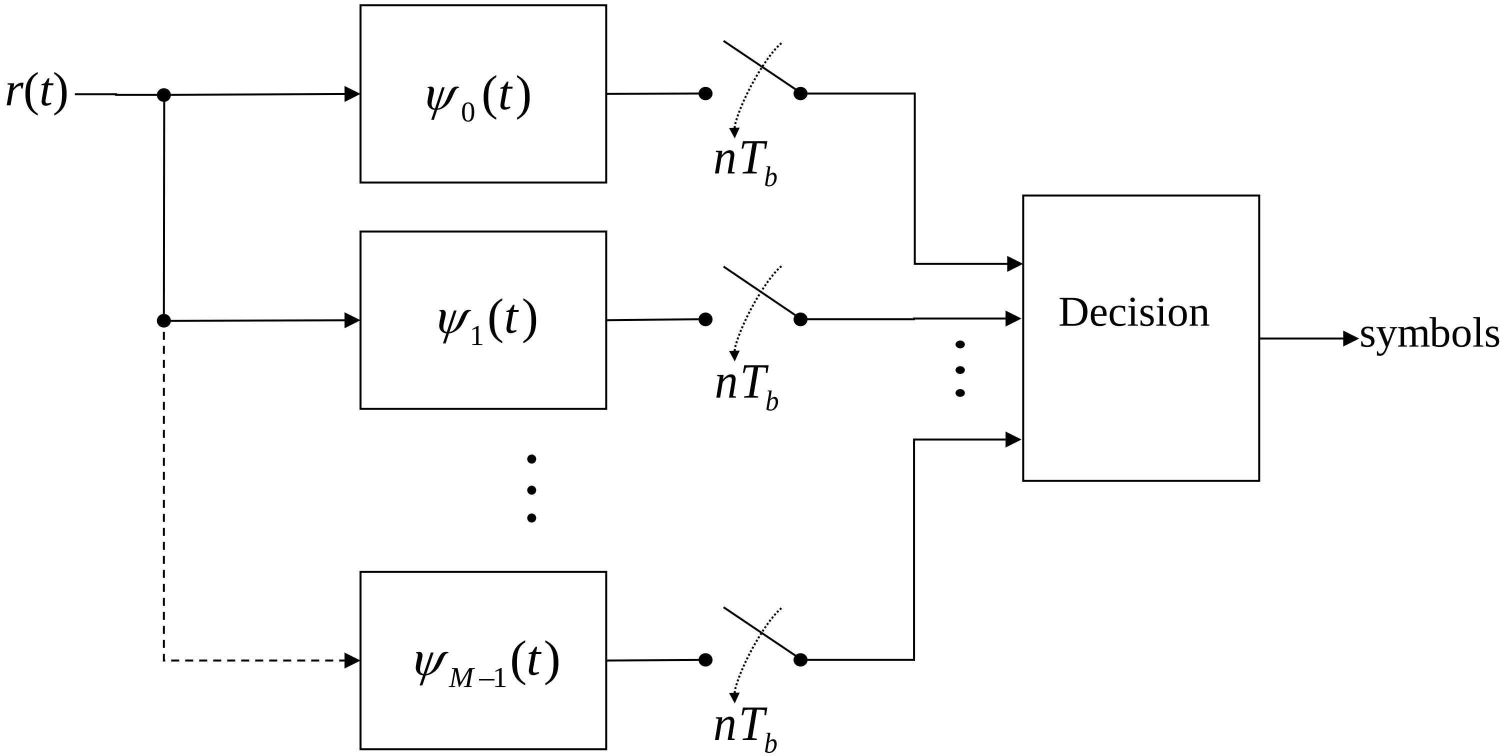
The receiver is cheaper with antipodal waveforms, requiring half the number of correlators than otherwise

The performance is better with antipodal and orthogonal waveforms.

These arguments are valid for passband communication schemas too.

# M-ary Matched-Filter Receiver

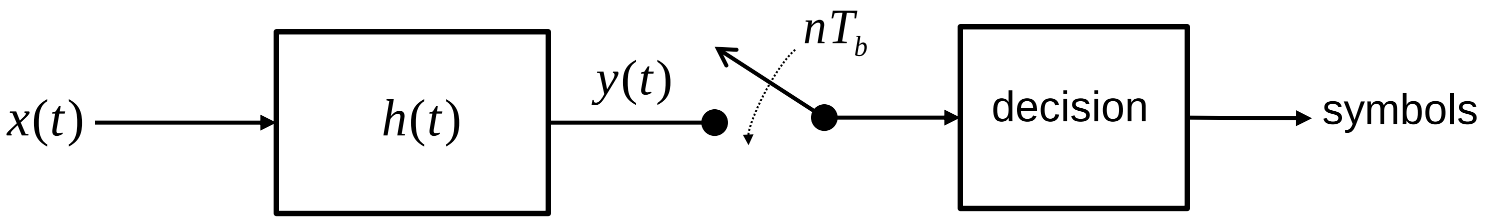
Now, think of a filter set that maximizes the corresponding output values at the end of finite duration waveform



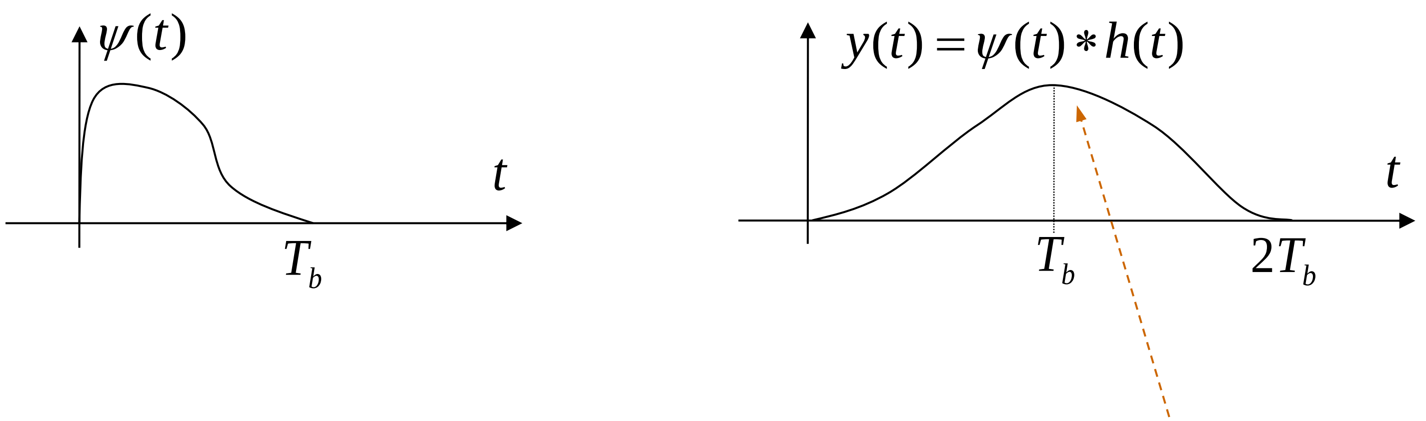
## Matched-Filter

Think of filter that maximizes the output value at the end of finite duration waveform

$x(t) = \psi(t)$ for $0 < t < T_b$



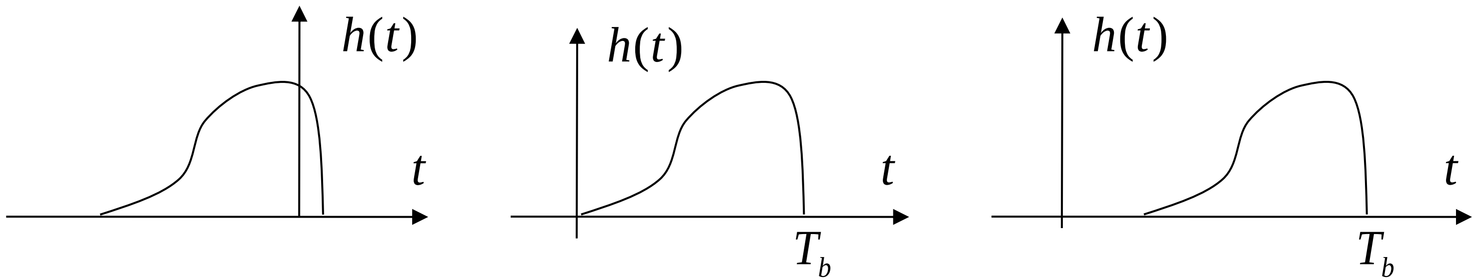

$$y(t) = x(t) * h(t) = \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau$$




For maximum probability of correct decision, we want this value as big as possible

It turns out that $h(t) = \psi(-(t+c))$ does the job

The question is, "what should be the value of $c$ ?"



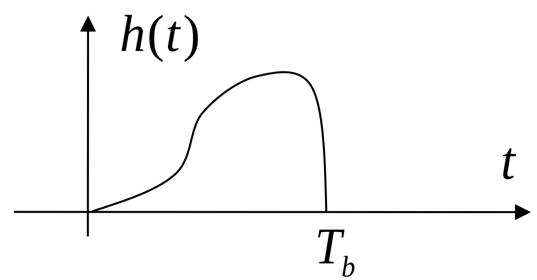

$c > -T_b$ $\qquad$ $c = -T_b$ $\qquad$ $c < -T_b$

not causal

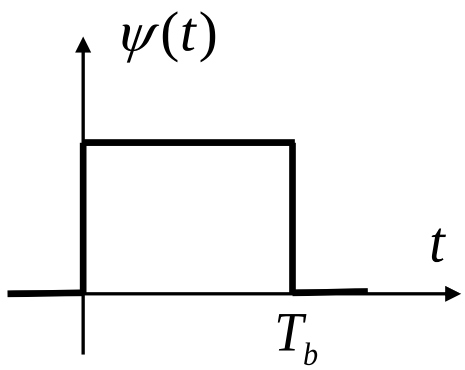
has unnecessary delay

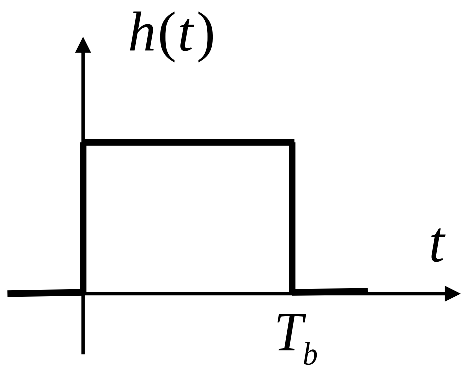
so, we select this

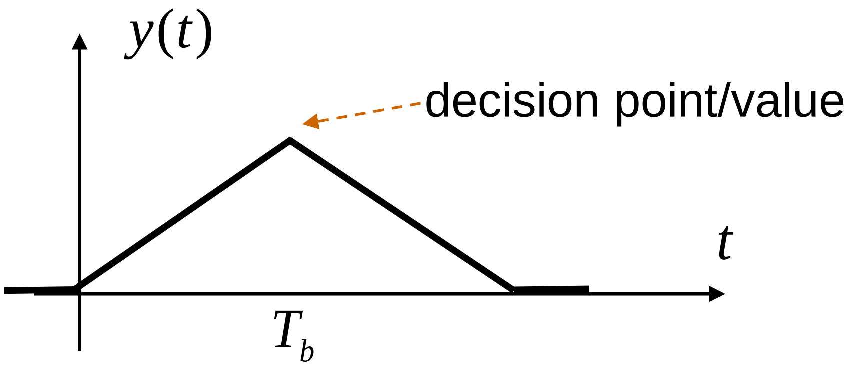
Matched Filter
Impulse Response



For rectangular pulses the filter is identical with the waveform

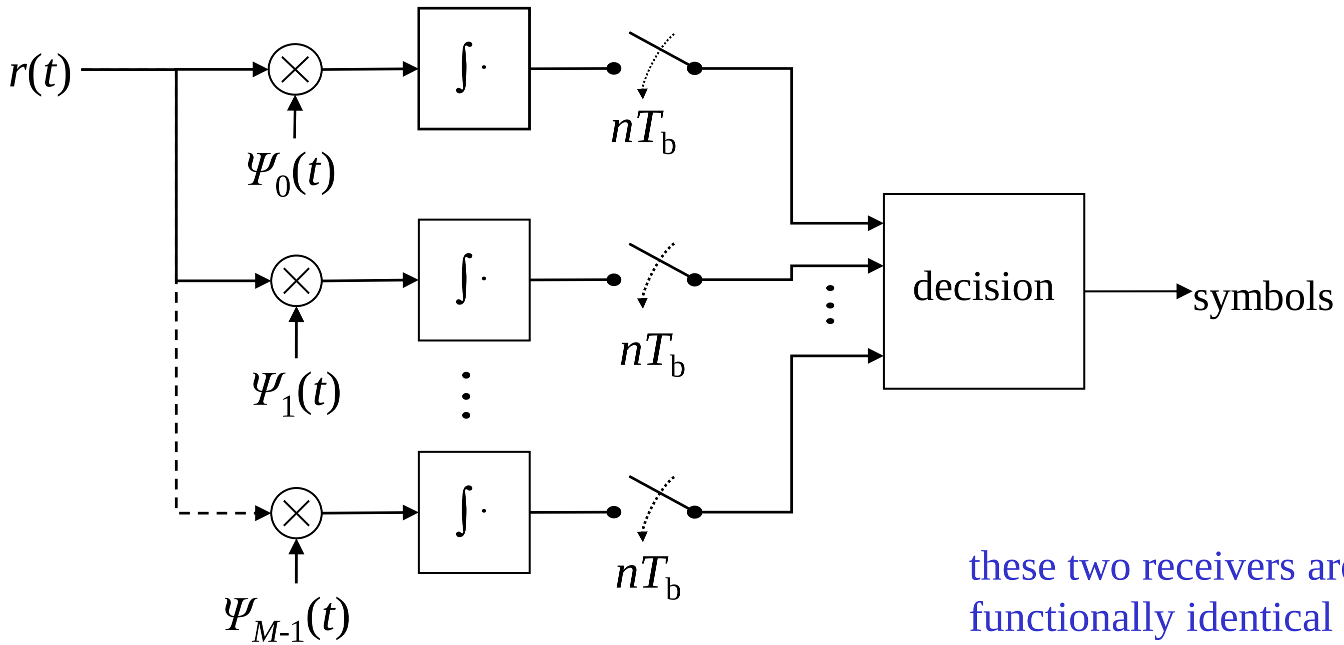


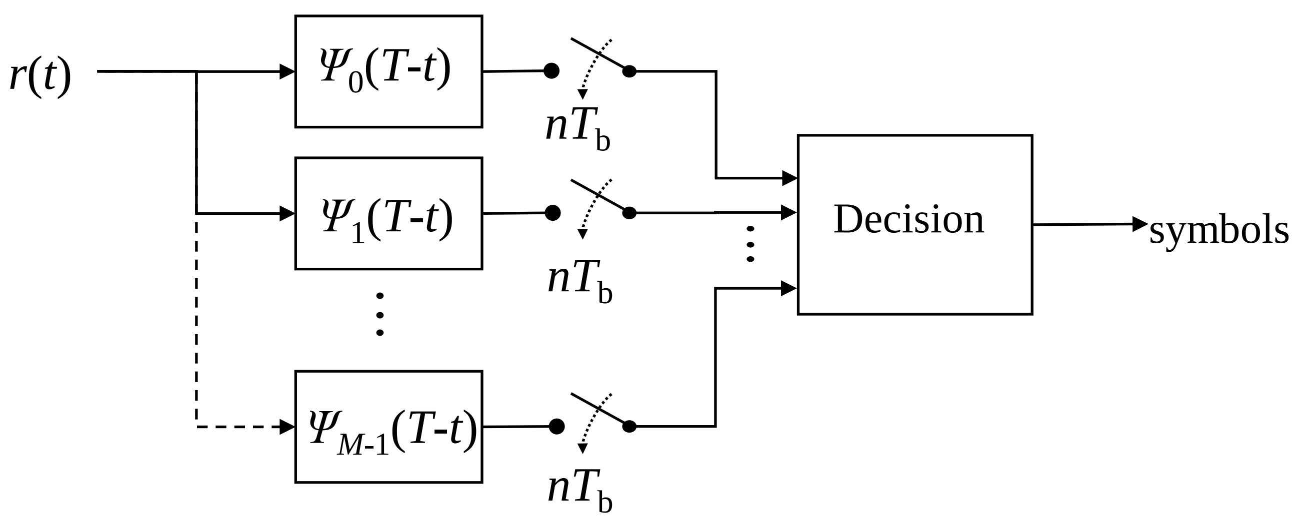




note that the result is the same with the output of correlator

Correlator and Matched-Filter Receivers are functionally identical



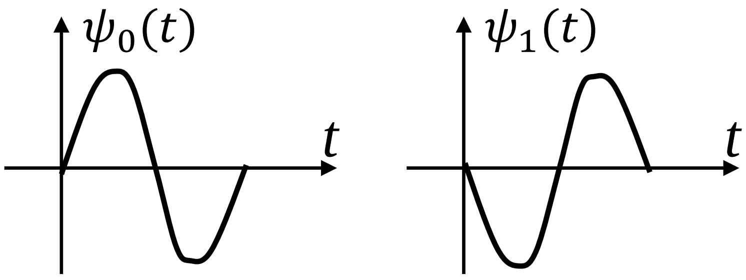

these two receivers are
functionally identical



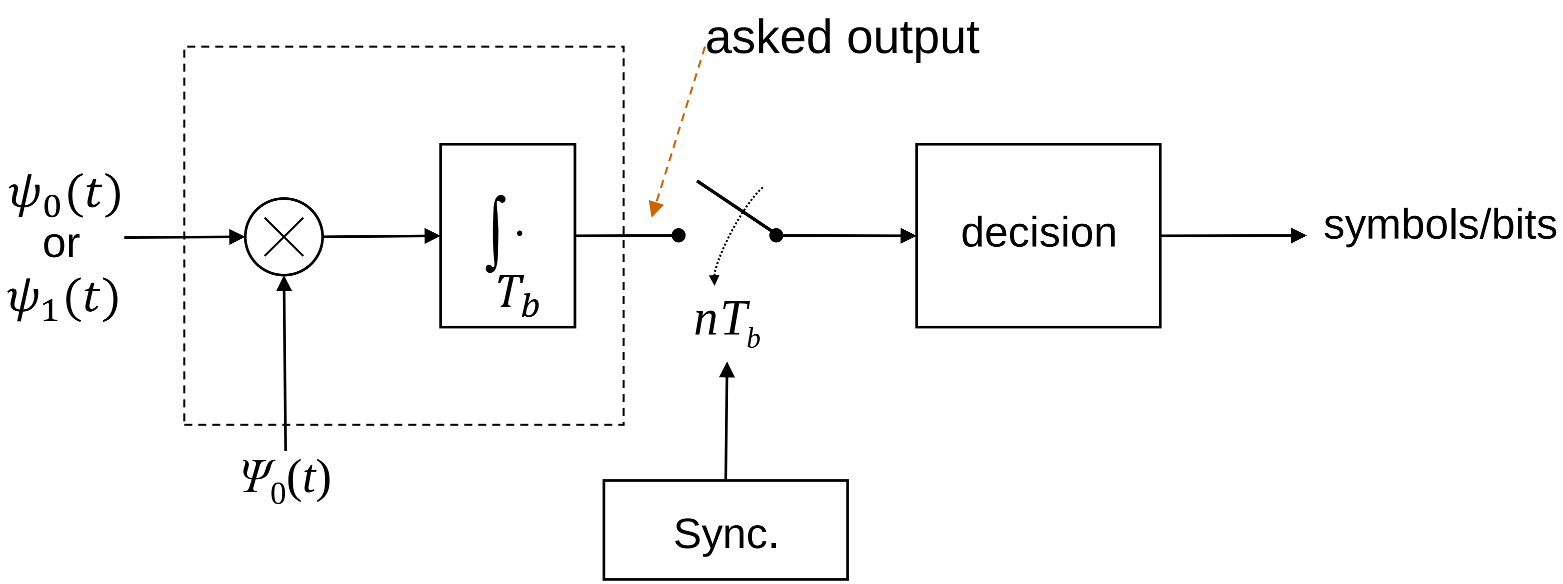
# Example

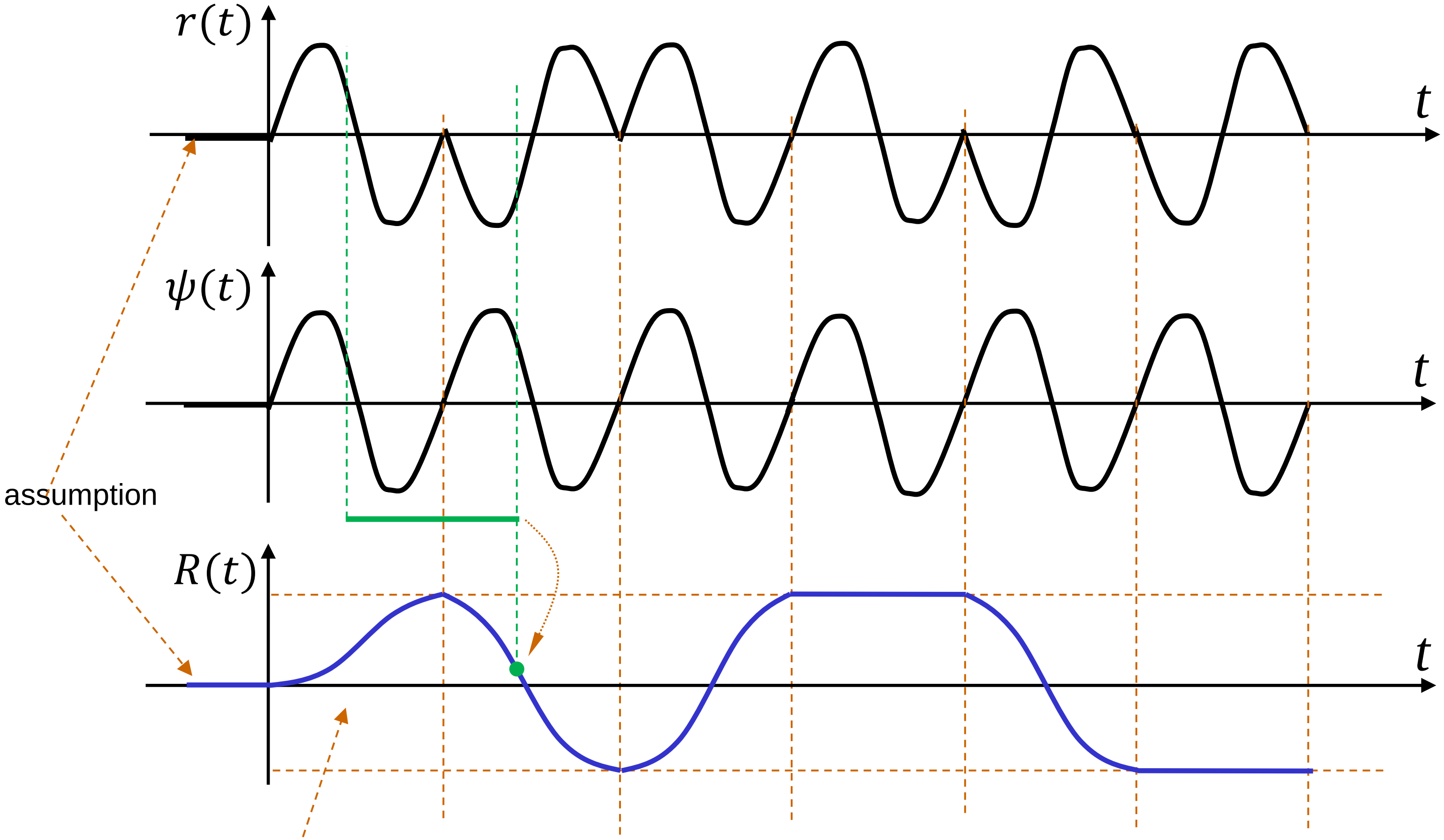
Let us assume that a 2-ary PAM system uses $\psi = \begin{cases} \pm \sin\left(\frac{2\pi t}{T_b}\right), & 0 < t < T_b \\ 0\,, & otherwise \end{cases}$

to represent binary 0 and 1.




Determine in-sync correlator output for the signal representing binary stream 010011





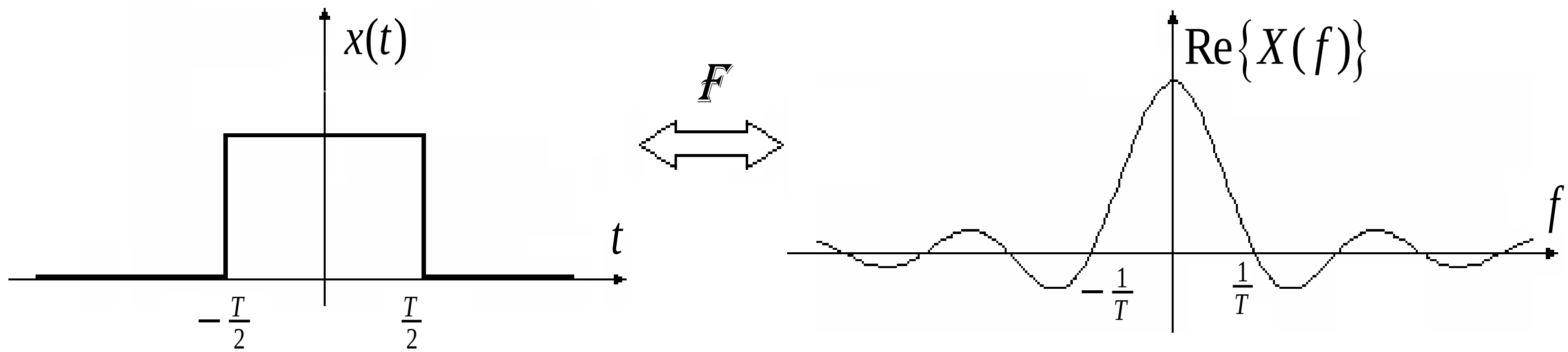

$$\int_0^t sin^2\left(\frac{2\pi\tau}{T_b}\right)d\tau$$

either monotonically increasing/decreasing or staying the same (excluding noise)

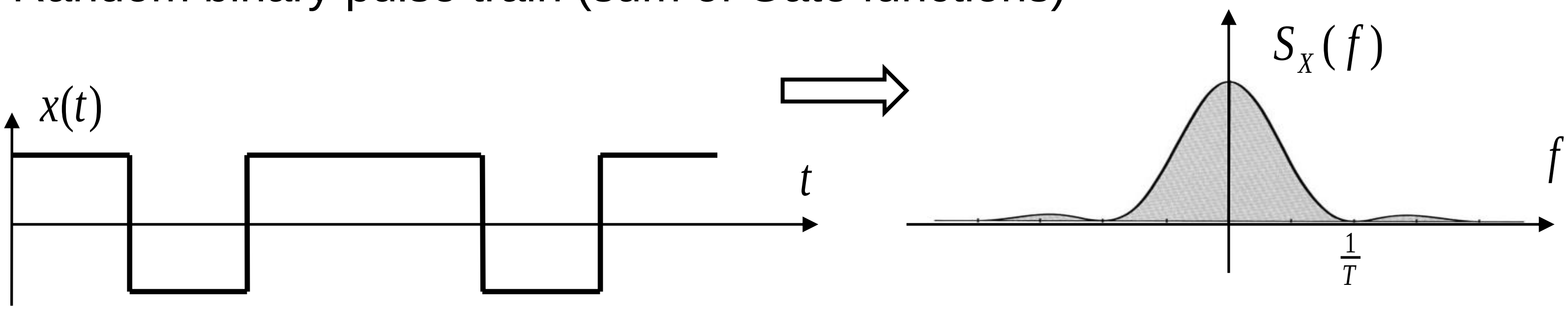
decision points : $nT_b$

# Frequency Characteristics of PAM

A single rectangular pulse (Gate function)

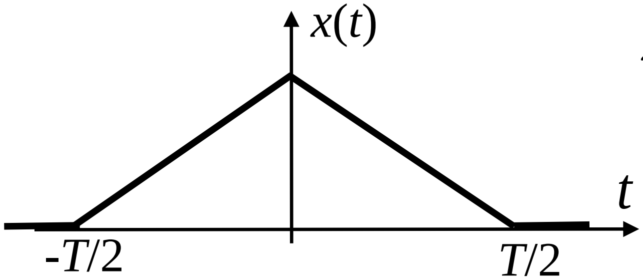



Random binary pulse train (sum of Gate functions)




A baseband signal extending towards infinity

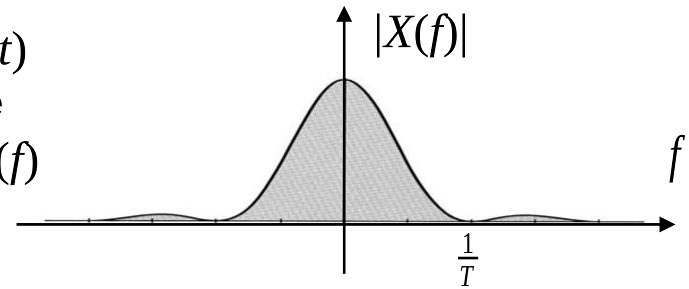
# Frequency Characteristics of Some Waveforms

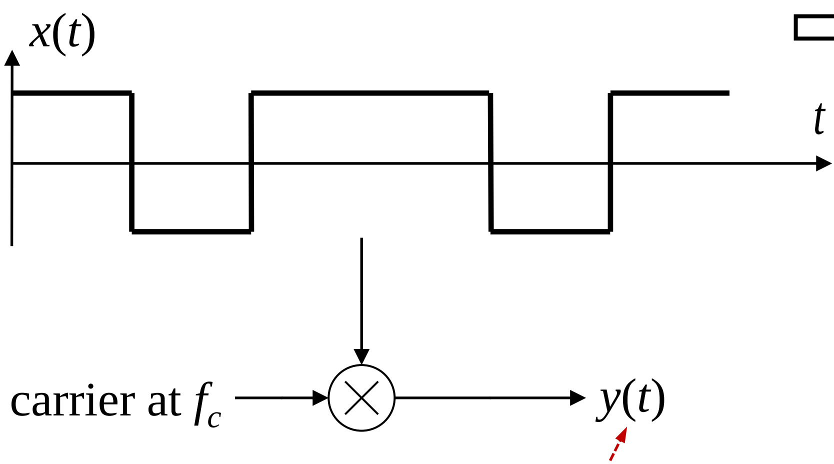


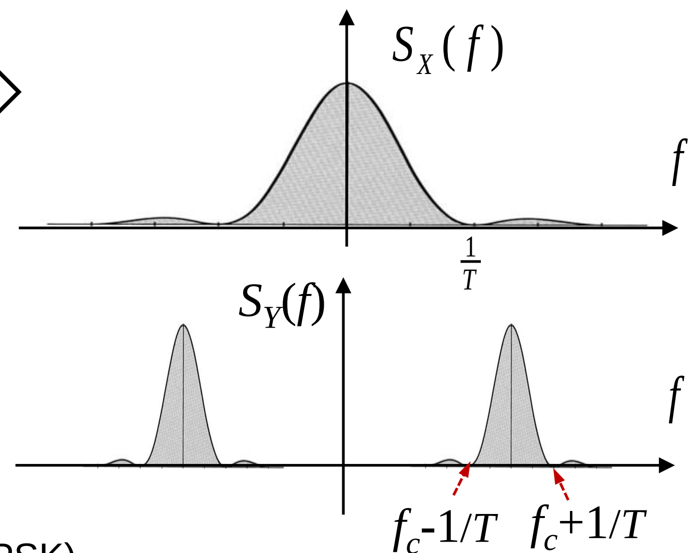

$x(t)=\Pi(t)*\Pi(t)$

and therefore

$X(f)=\Pi(f)\Pi(f)$



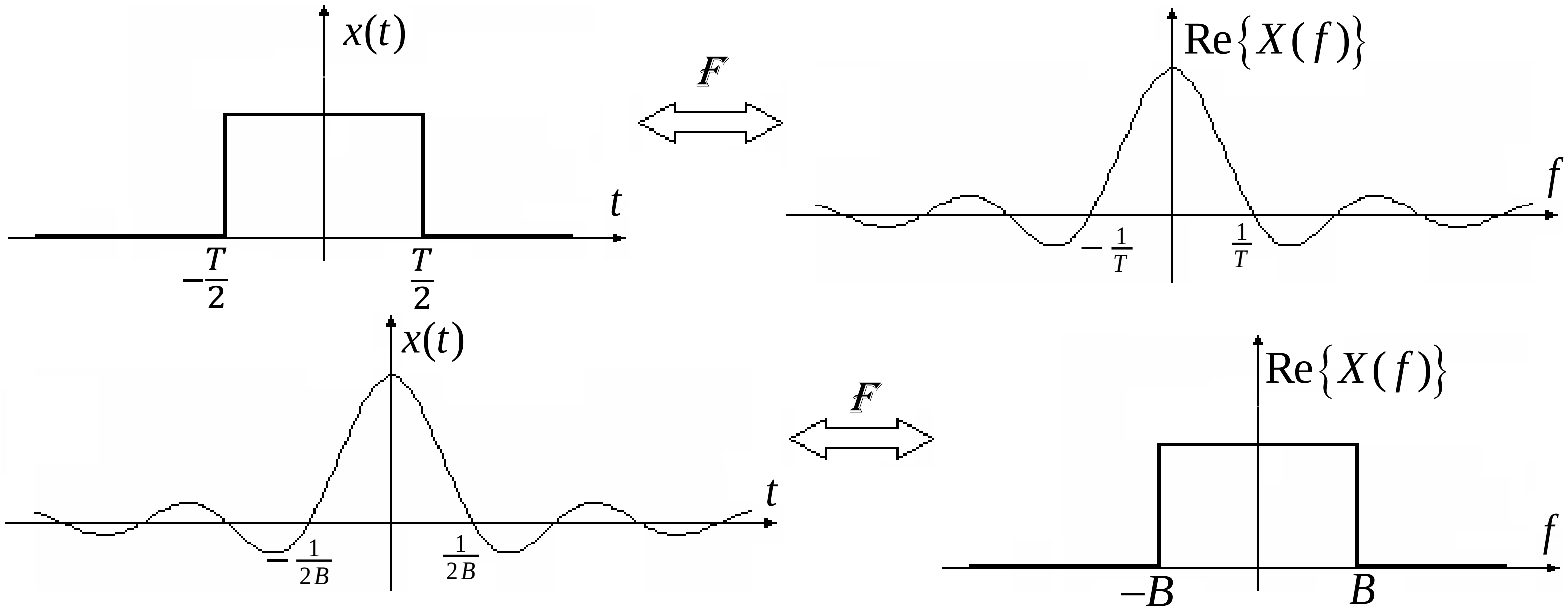




antipodal sinusodal pulses (BPSK)

It seems that we cannot avoid sinc-like spectrums

Hmw: Try to estimate the spectral shapes for QPSK, M-QAM and 2-FSK

# Waveform Shaping to Limit the Bandwidth

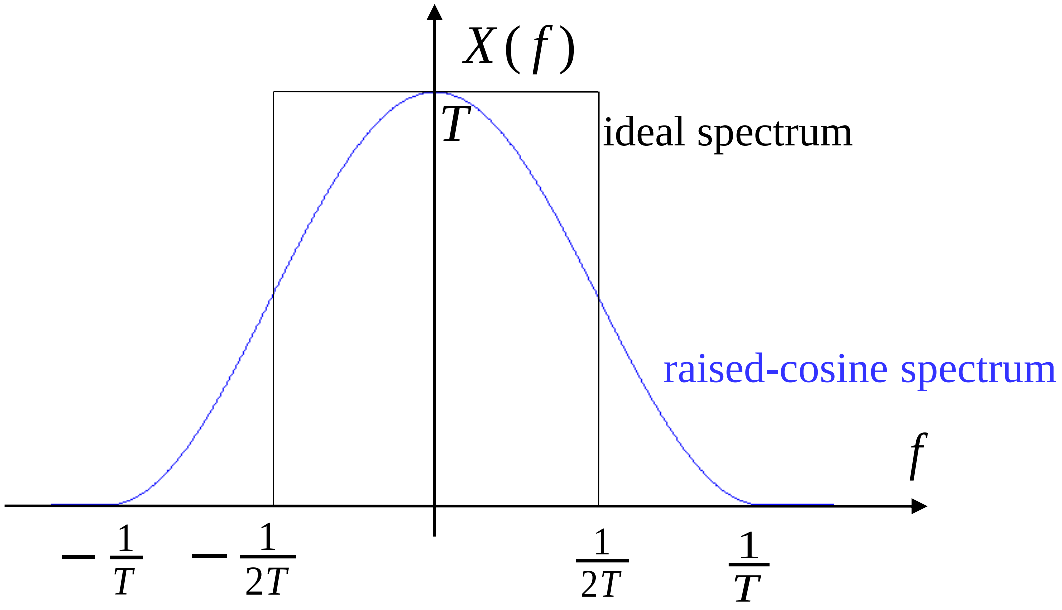



An ideally limited spectrum requires a waveform with infinite length

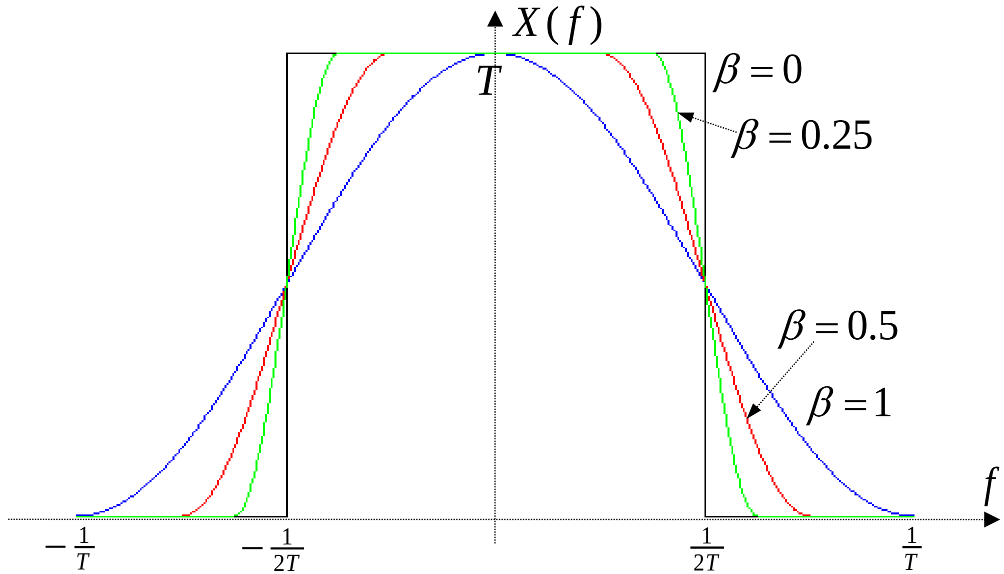
Therefore, not possible

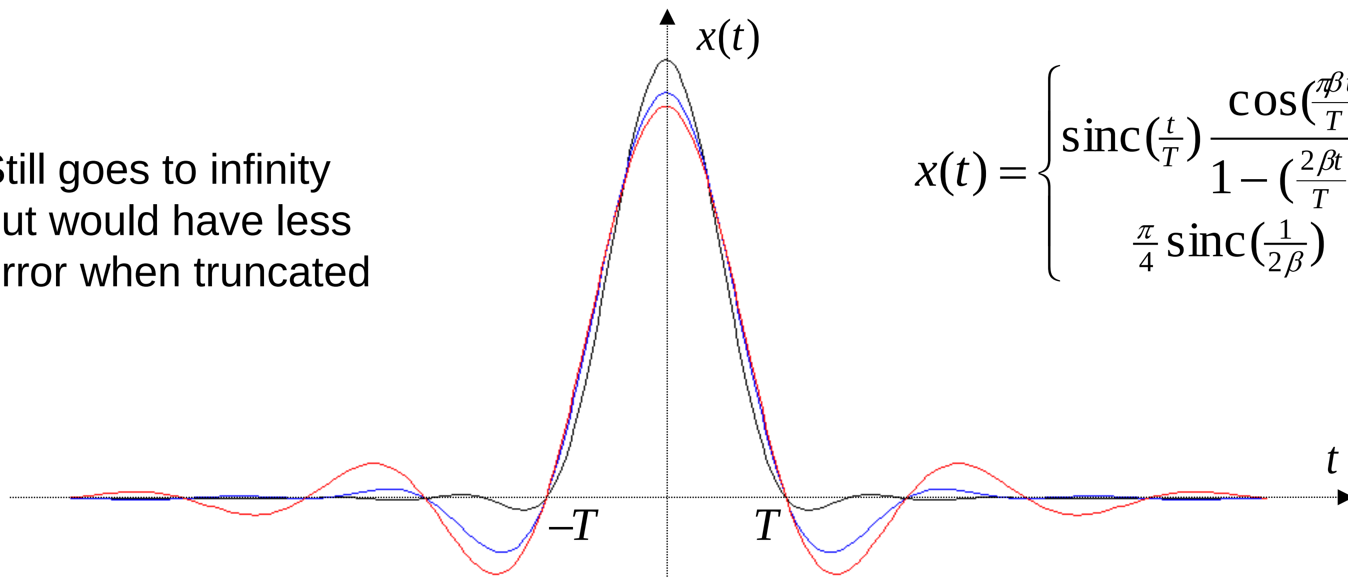
# A Compromise

$$X(f)=\begin{cases} T & , \quad |f|\le \frac{1-\beta}{2T} \\ \frac{T}{2}\left[1+\cos\left(\frac{\pi T}{\beta}\left(|f|-\frac{1-\beta}{2T}\right)\right)\right] & , \quad \frac{1-\beta}{2T}<|f|\le \frac{1+\beta}{2T} \\ 0 & , \quad |f|>\frac{1+\beta}{2T} \end{cases}$$



# Raise-Cosine Spectrum and Pulses



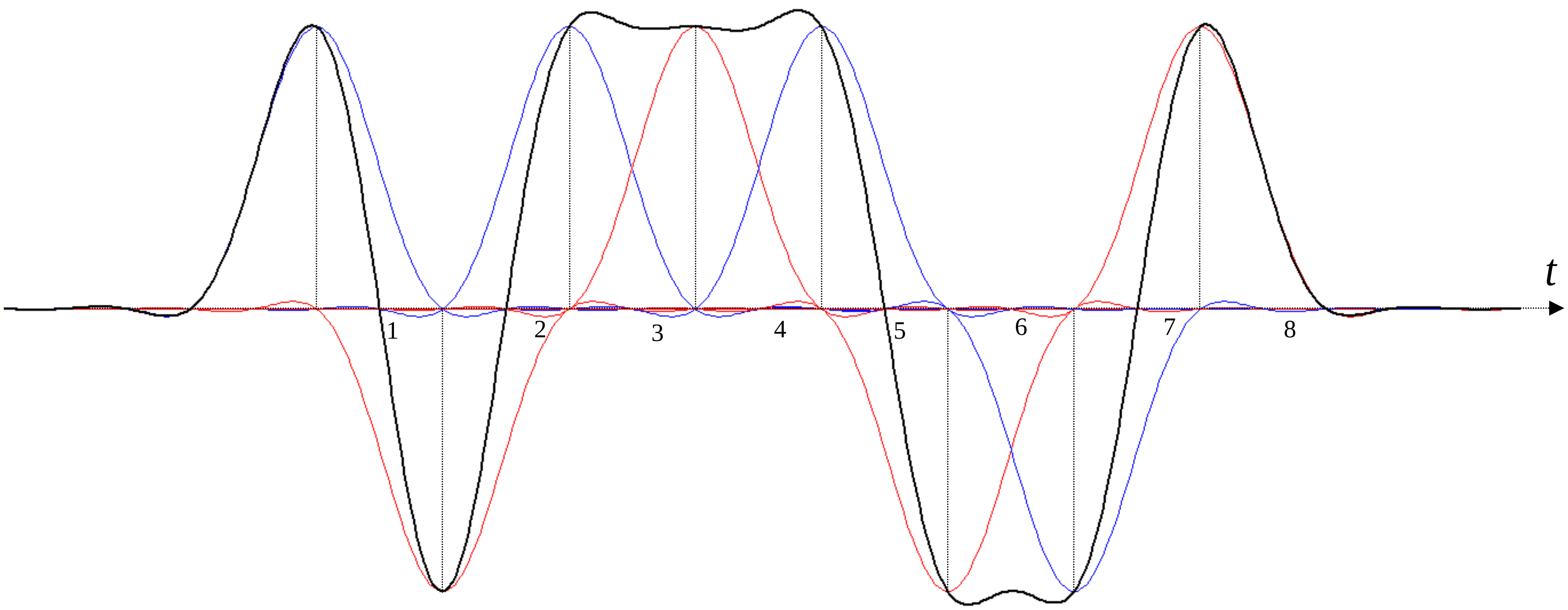




Still goes to infinity
but would have less
error when truncated

$$x(t) = \begin{cases} \mathrm{sinc}\left(\frac{t}{T}\right) \dfrac{\cos\left(\frac{\pi\beta t}{T}\right)}{1-\left(\frac{2\beta t}{T}\right)^2} \ , & t \neq \pm \frac{T}{2\beta} \\ \frac{\pi}{4}\,\mathrm{sinc}\left(\frac{1}{2\beta}\right) \ , & t = \pm \frac{T}{2\beta} \end{cases}$$

# Raise-Cosine Filtered Rectangular Pulse Train

is the sum of several sinc-like functions (you see that the pulses are smooth)




binary …10111001…

Property of raised-cosine : values at sinc-tops are preserved

We now obtained a binary channel signal with finite (almost) bandwidth

in baseband

What should we do to have a binary channel signal in high frequencies and

bandpass ?

The answer is : modulate a carrier using the baseband signal of course

# END