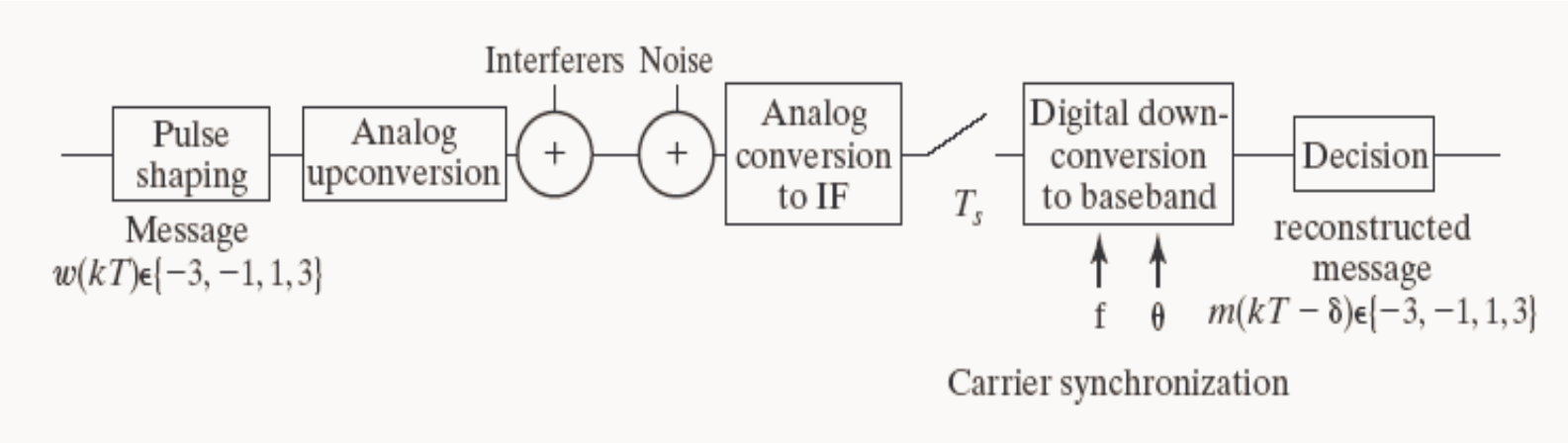
# Analog Up and Downconversion

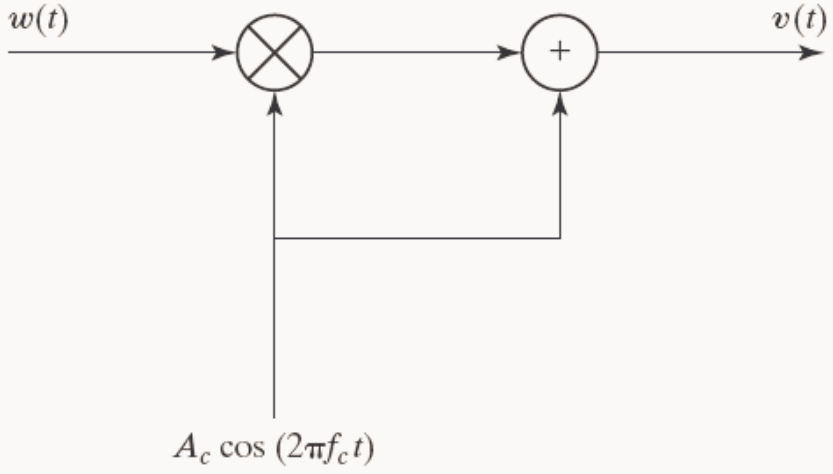
- The message symbols to reconstructed symbols portion of the PAM digital communication system

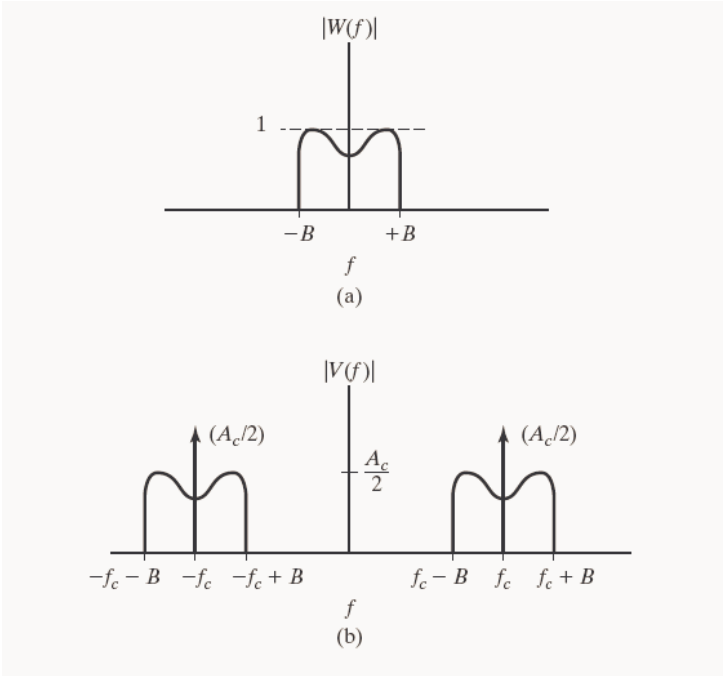


# Amplitude Modulation with Large Carrier

- *analog message signal*: *w*(*t*)
- *transmitted/modulated signal*:

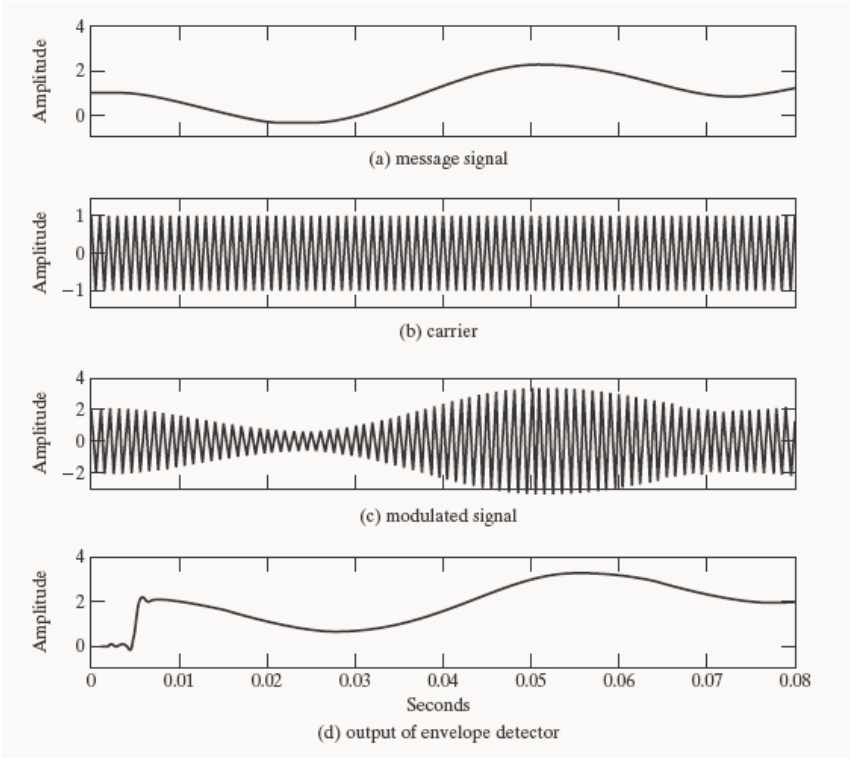
$$v(t) = A_c w(t)\cos(2\pi f_c t) + A_c \cos(2\pi f_c t)$$



# Demodulation

- *demodulation with envelope detector*: If $w(t) \geq -1$, envelope of $v(t)$ matches $w(t)$. Using a nonlinearity and LPF as envelope detector produces




  - *main advantage*: carrier phase and frequency synchronization not needed at receiver
  - *main disadvantage*: power needed for largecarrier does not reinforce message signal

# Amplitude Modulation with Suppressed Carrier

- *analog message signal*: *w*(*t*)
- *transmitted/modulated signal*:

$$v(t) = A_c w(t) \cos(2\pi f_c t)$$

- *transmitted signal spectrum*:

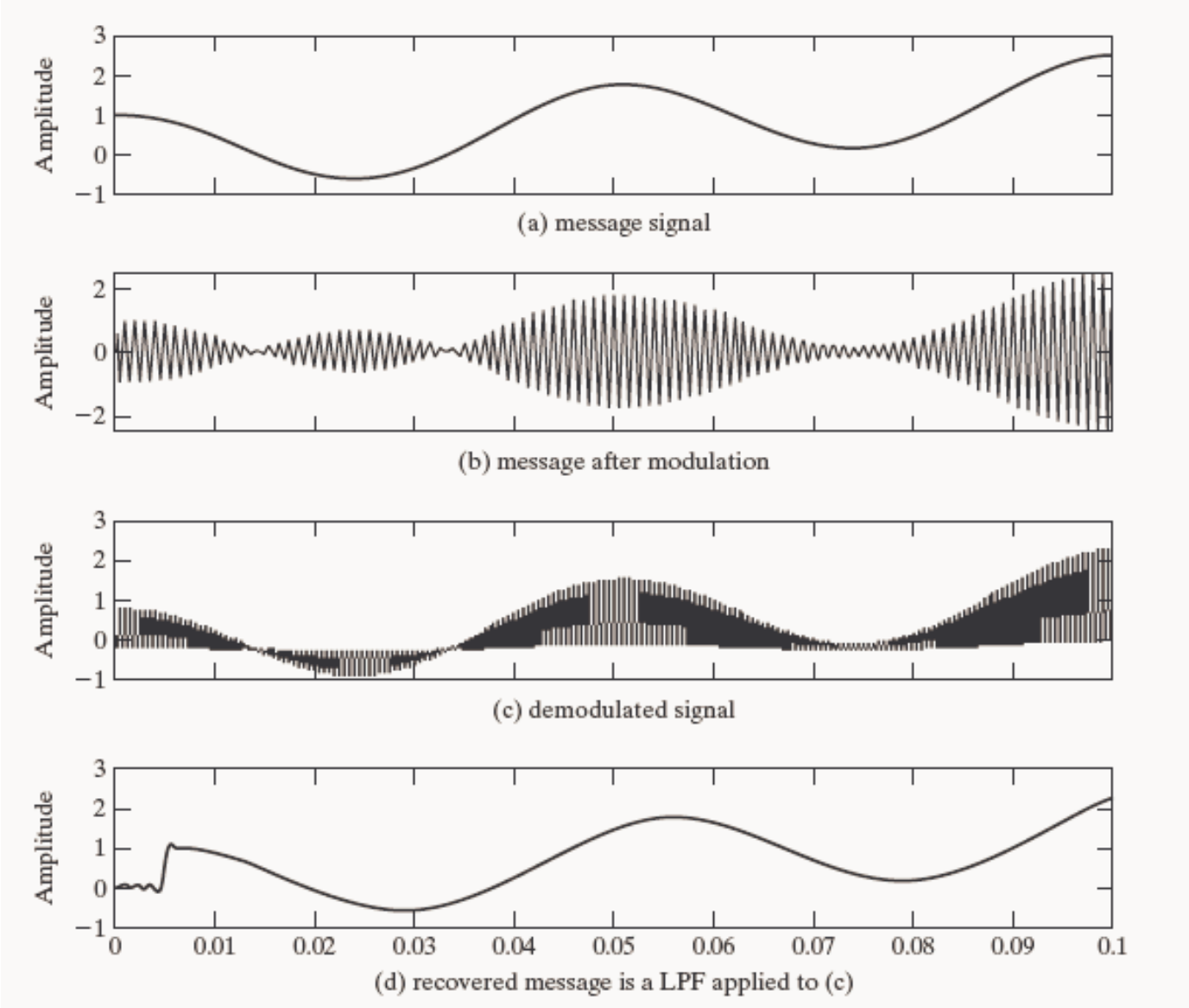
$$V(f) = \frac{1}{2} A_c W(f + f_c) + \frac{1}{2} A_c W(f - f_c)$$

- *ideal demodulation with synchronized mixing and LPF*:

$$m(t) = \mathrm{LPF}\{v(t)\cos(2\pi f_c t)\} = \frac{1}{2} A_c W(f)$$

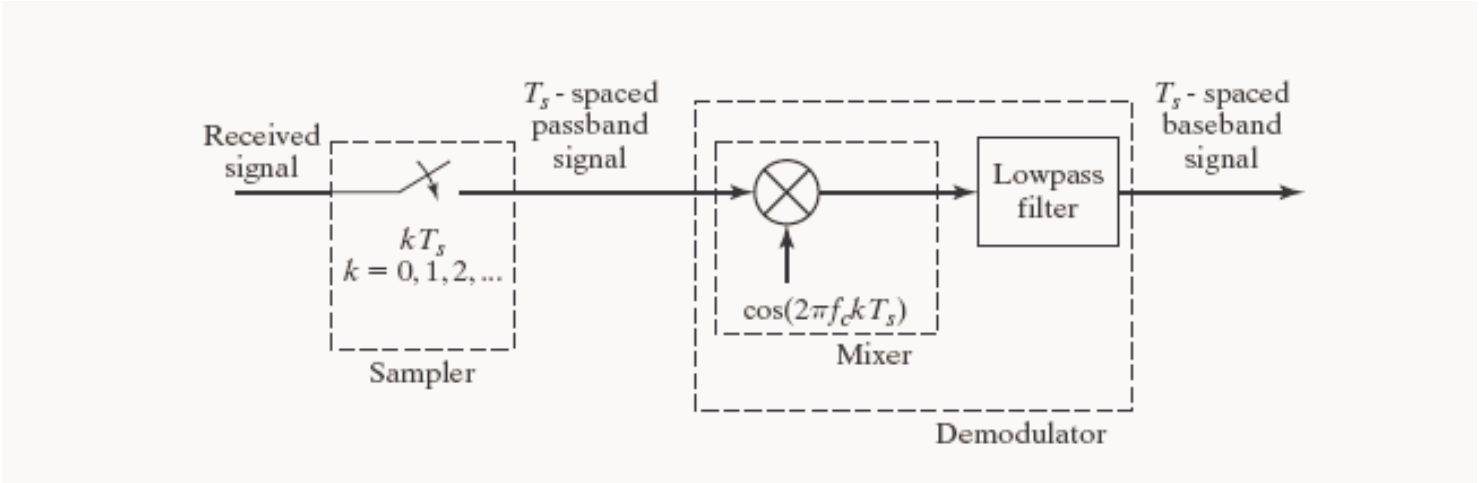
- *main advantage*: extra power not needed for added carrier
- *main disadvantage*: carrier phase and frequency synchronization needed at receiver

# Example


Amplitude
3
2
1
0
−1
(a) message signal
Amplitude
2
0
−2
(b) message after modulation
Amplitude
3
2
1
0
−1
(c) demodulated signal
Amplitude
3
2
1
0
−1
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
(d) recovered message is a LPF applied to (c)

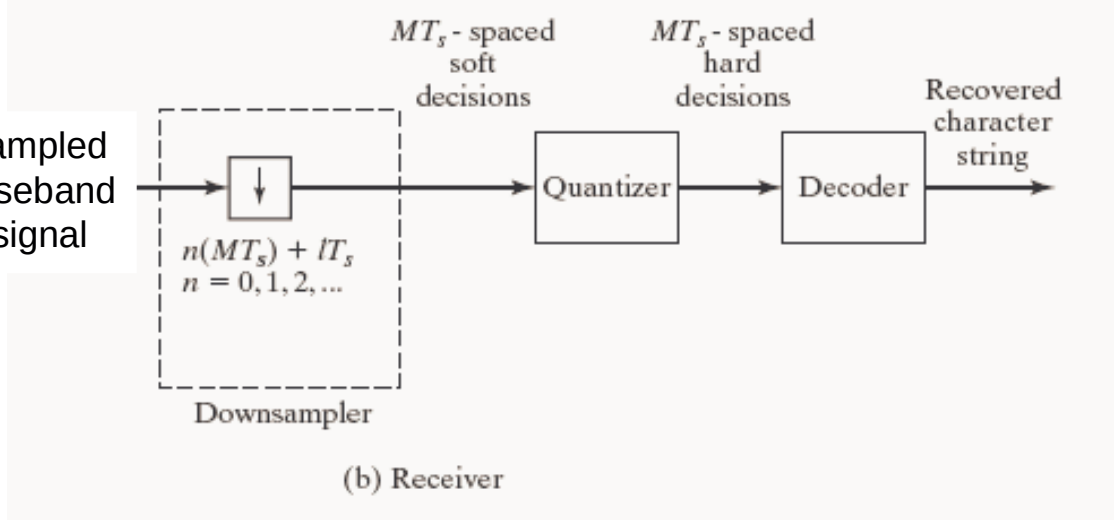
# Naive/Ideal Demodulation

- With a perfect (i.e. gain with delay) channel and satisfactory carrier, baud timing, and frame synchronization, the ideal PAM system



# Naive/Ideal Demodulation

- Ideal PAM receiver

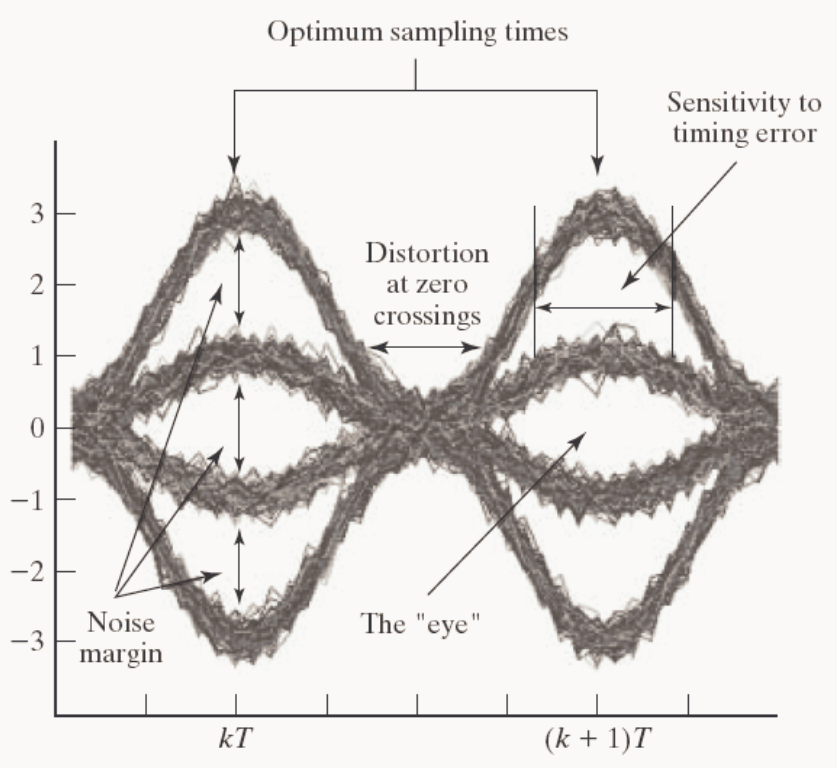


# Sampling at the Receiver

- Free running sampler output

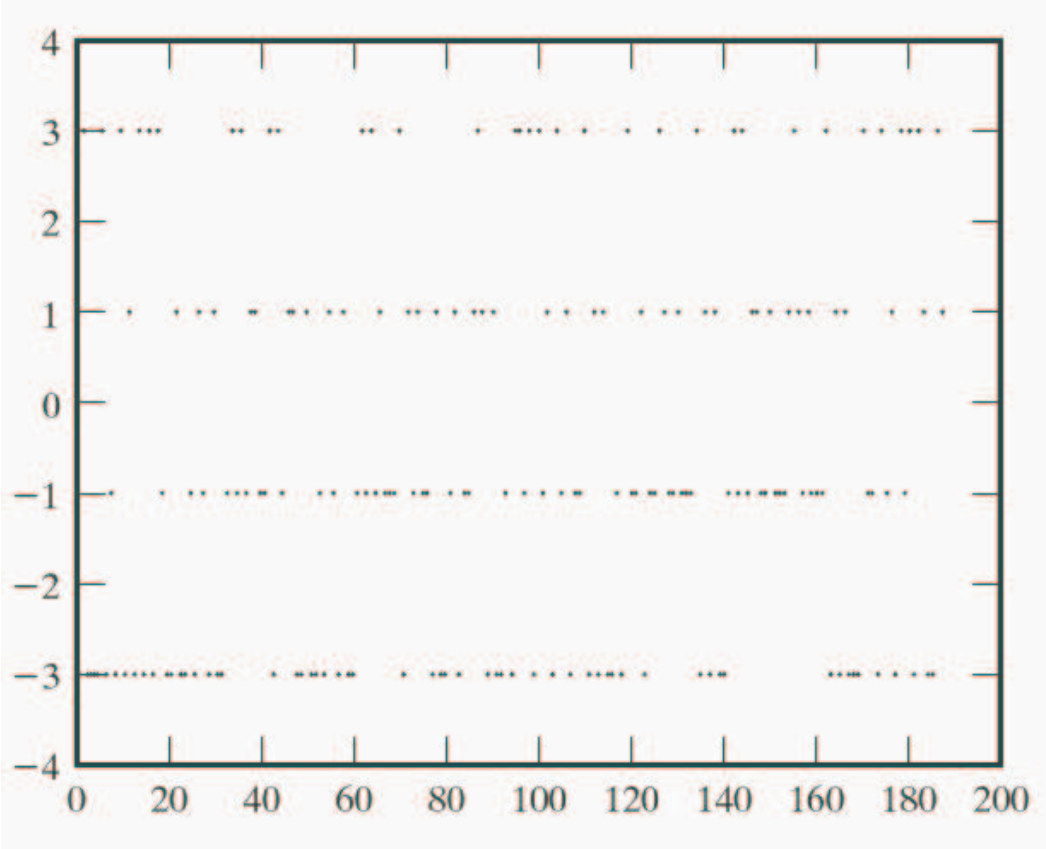
$$r(t)|_{t=kT_s} = \sum_{i=0}^{N-1} m[i]p(kT_s - iT)\cos(2\pi f_c kT_s)$$

- Recall eye diagram
- Sampling clocks of A/D and D/A at TX and RX
- We need to track optimum sampling times



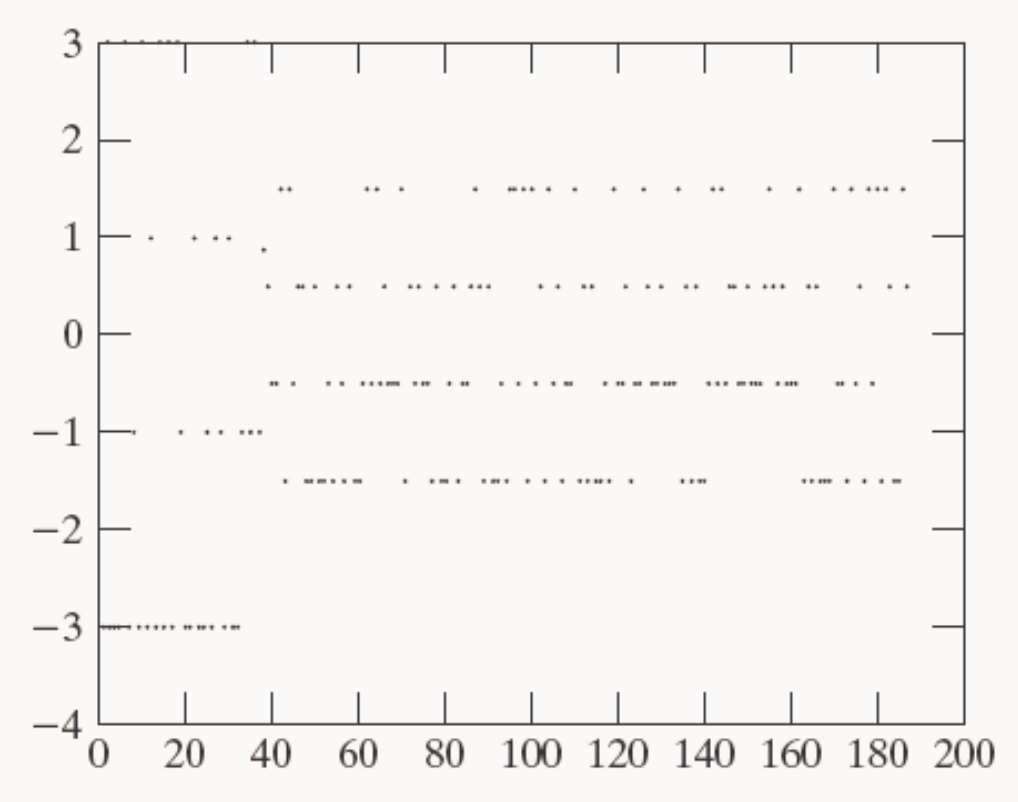
# Sampling at the receiver

- Soft decision samples for 4-level PAM
- Because the soft decisions are so close to the alphabet levels, there are no decision errors and no symbol errors.



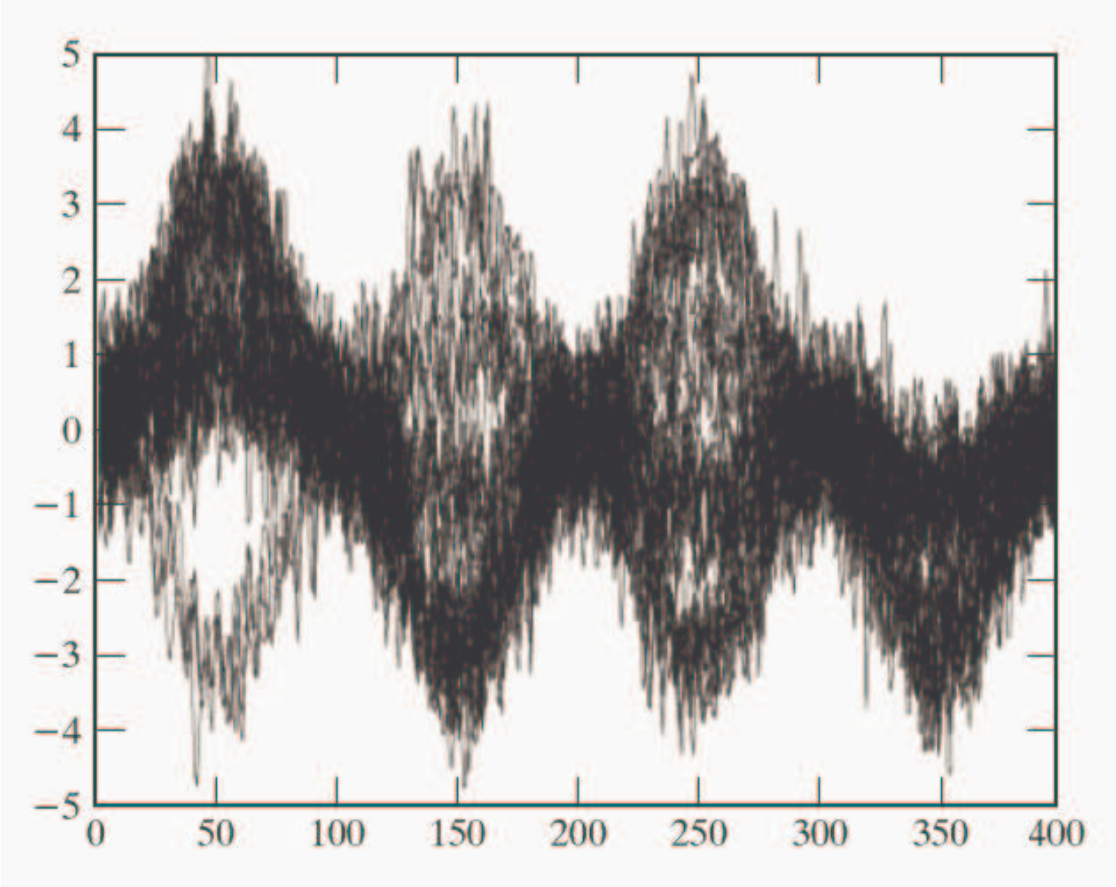
# Impairment

- *Impairment*: At time representing 20% of duration of simulation window, the channel gain changes abruptly from 1 to 0.5.



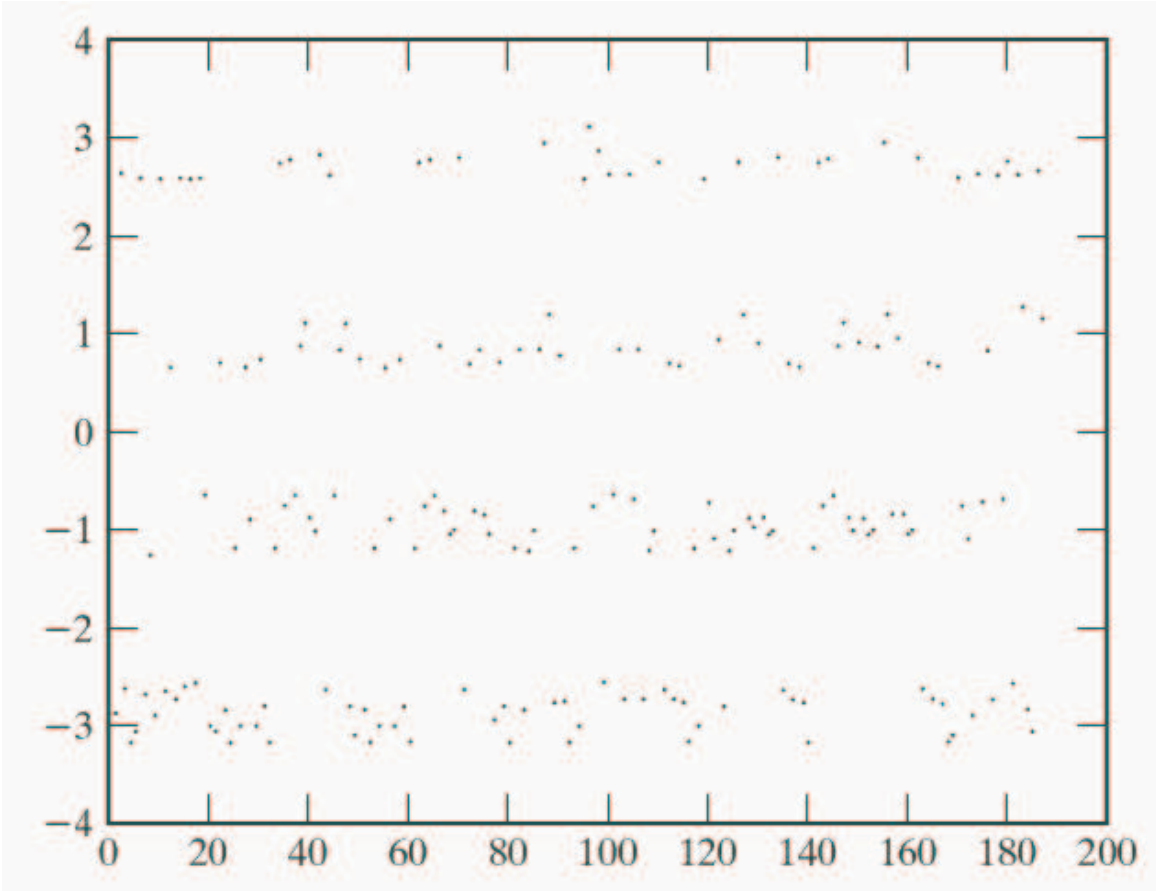
# Noise

- Noisy signal



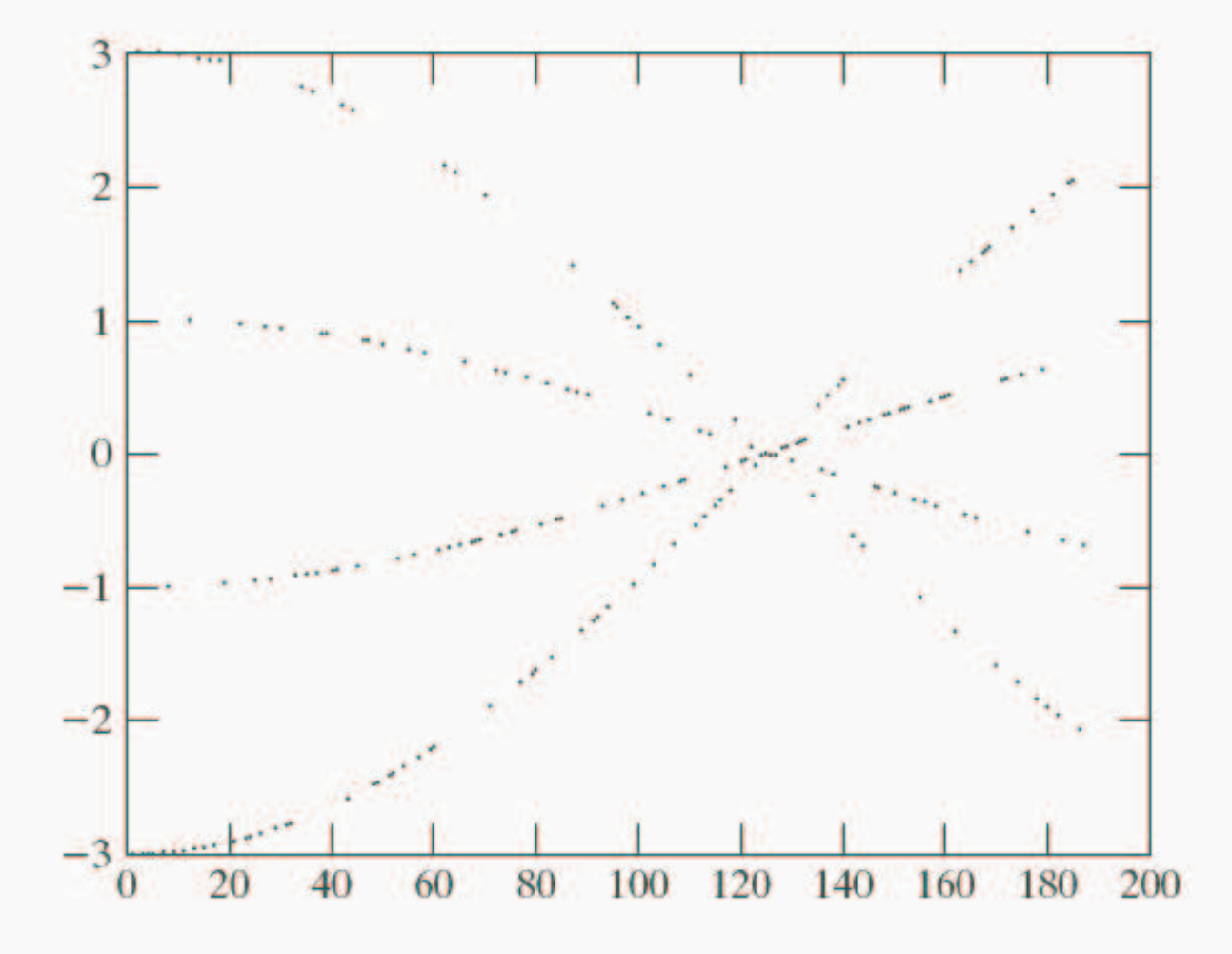
# Sampling of Noisy signal

- Sampling of noisy signal, decision boundaries are still visible



# Carrier Offset

- The carrier frequency offset appears as a low frequency amplitude modulation of the desired outputs.



# Switch to PAM Demodulation

- Downconversion by setting your receiver pointer to the beginning of your input buffer.
- First the receiver is on and transmitter is off
- Transmitter starts with marker and PN sequence
- When transmitter starts, carrier detect will switch to PAM downconversion