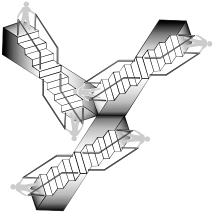
STUFF HAPPENS

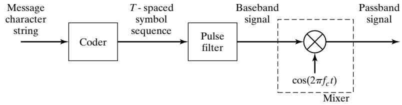
- ⋆ A Naive/Ideal Communication System
- ⋆ Flat Fading
- ⋆ What if ...



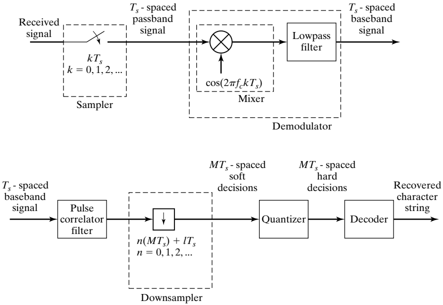
idealized system

A Naive/Ideal Communication System

With a perfect (i.e. gain with delay) channel and satisfactory carrier, baud timing, and frame synchronization, we simulate this PAM system.



(a) Transmitter



(b) Receiver

A ... System (cont'd)

TRANSMITTER

- *text message*: 01234 I wish I were an Oscar Meyer wiener 56789
- *coding*: text characters via 8-bit ASCII to 4-PAM $m[i]$
- *baud interval*: $T = 1$ time unit
- *pulse shape*: T-wide Hamming blip $p(\cdot)$
- *carrier frequency*: $f_c = 20$
- *carrier phase*: 0

RECEIVER

- *sampler period*: T_s $(= T/M)$
- *oversample rate*: $M = 100$

A ... System (cont'd)

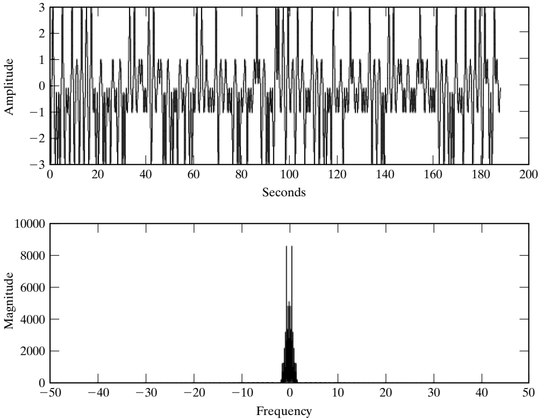
- *free running sampler output*:

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

- *mixer frequency*: $f_c = 20$
- *mixer phase*: 0
- *demodulator LPF*: `firpm(fl,fbe,damps)` with `fl` = 50, `fbe` = [0 0.5 0.6 1], and `damps` = [1 1 0 0]
- *pulse correlator filter*: T-wide Hamming blip
- *downsampler baud timing*: $\ell = 125$ (determined experimentally)
- *quantizer*: to nearest element in $\{\pm 1, \pm 3\}$
- *decoder*: 4-PAM to 8 bits via reverse ASCII to text (with frame synchronization assured by indexing from first symbol set by baud timing)

A ... System (cont'd)

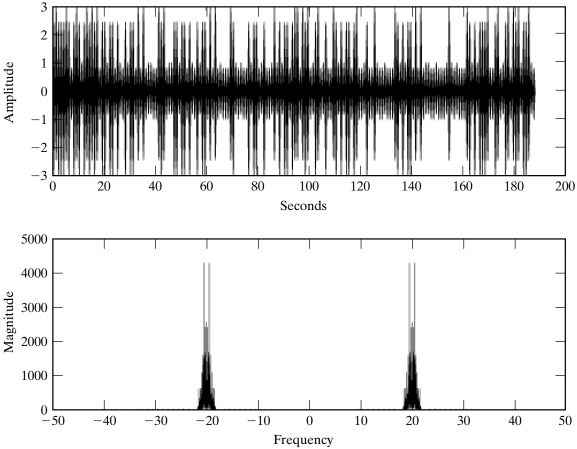
Transmitter baseband signal and magnitude spectrum



Note that frequency axis is limited to minus to plus Nyquist frequency, i.e. half of oversample frequency.

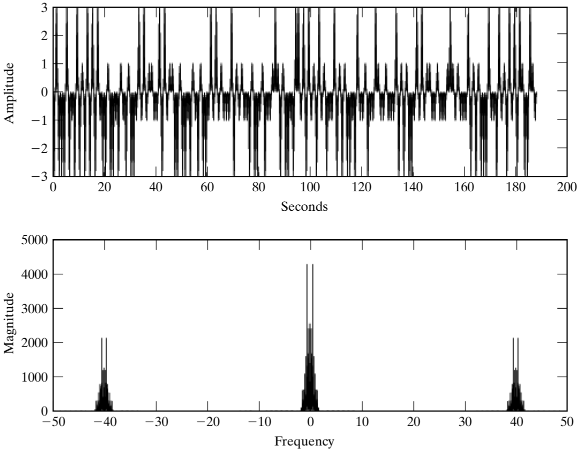
A ... System (cont'd)

Transmitter passband signal and magnitude spectrum



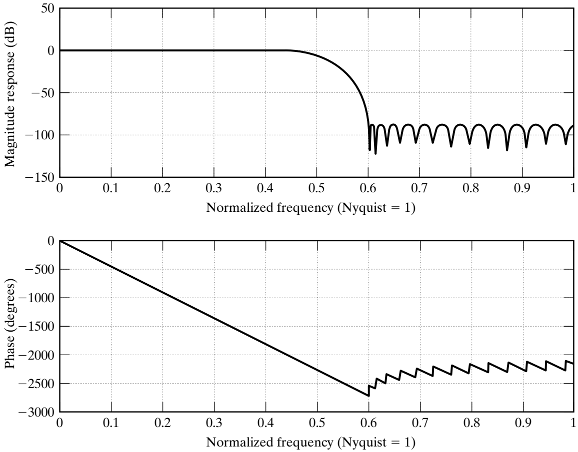
A ... System (cont'd)

Receiver mixer output and magnitude spectrum



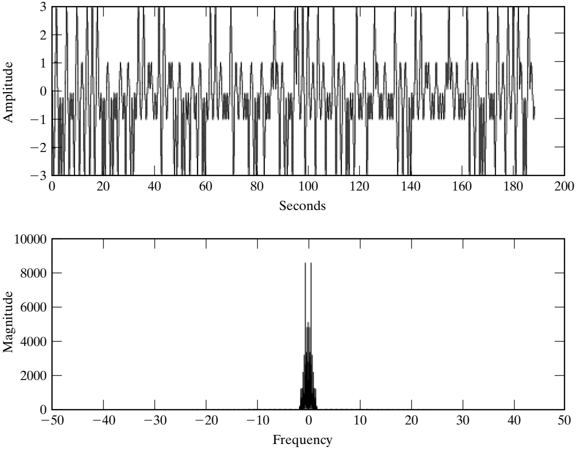
A ... System (cont'd)

Receiver post-mixer LPF frequency response



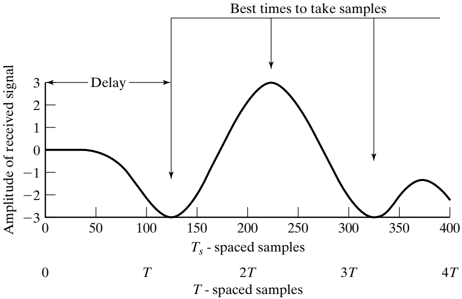
A ... System (cont'd)

Receiver downconverter-LPF output and magnitude spectrum



A ... System (cont'd)

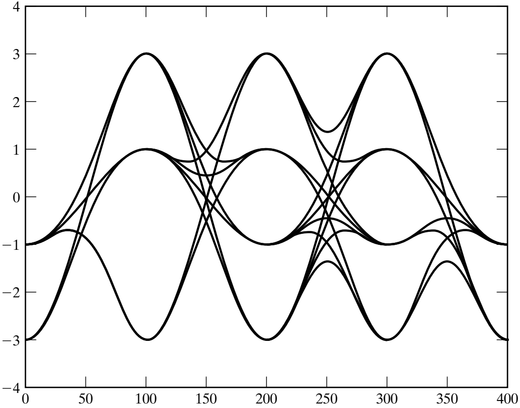
First 400 samples of pulse correlator filter output



This reveals $\ell = 125$ for first symbol sample (or baud) time. ($125 =$ half length of lowpass filter in downconverter and half length of correlator filter and half a symbol period)

A ... System (cont'd)

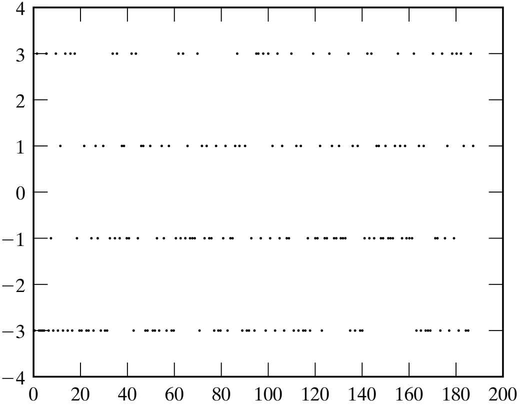
Overlay of successive $4T$-wide correlator output segments starting on first baud time



Note recurrence of pulse peaks at successive T-wide intervals.

A ... System (cont'd)

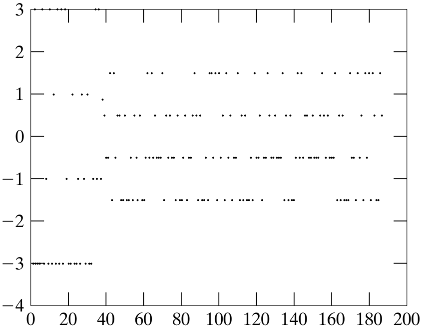
Soft Decisions Constellation Diagram History



Because the soft decisions are so close to the alphabet levels, there are no decision errors and no symbol errors.

Flat Fading

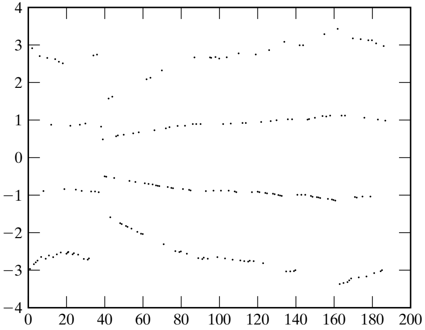
Impairment: At time representing 20% of duration of simulation window, the channel gain changes abruptly from 1 to 0.5.
Effect: Soft decisions in "ideal" system receiver



The soft decisions have all moved inside 2 in magnitude, meaning that decision device will never produce $\pm 3 \Rightarrow$ lots of errors.

Flat Fading (cont'd)

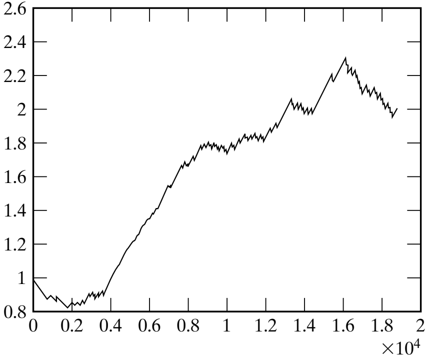
Fixed: Soft decisions with inclusion of AGC



Decisions correct once top and bottom stripes in constellation diagram history have magnitude > 2.

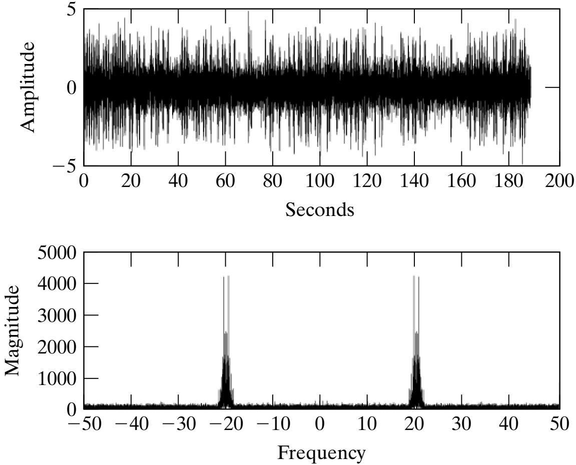
Flat Fading (cont'd)

Adapted gain time history: Starts at 1; ends near 2.



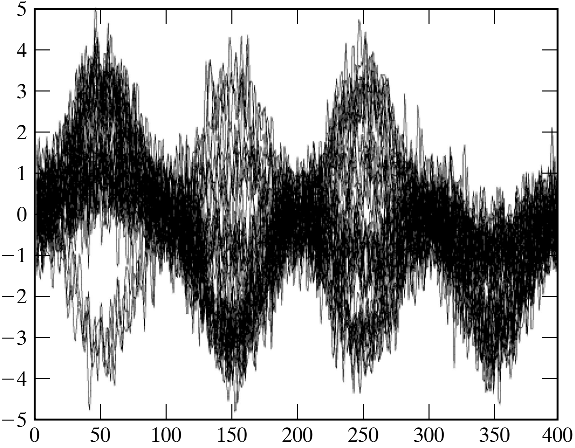
What if ...

Channel noise: Noisy received signal and spectrum



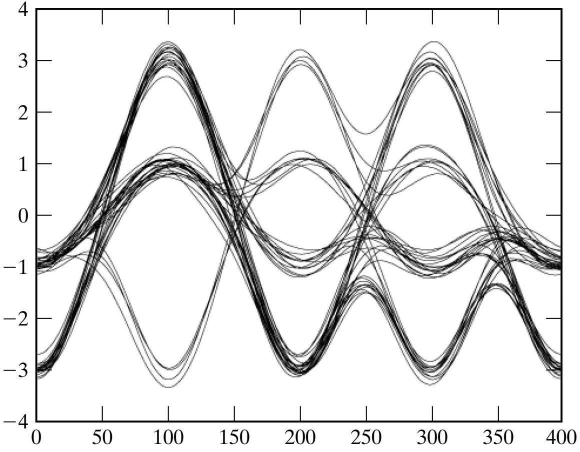
What if ... (cont'd)

Channel noise (cont'd): Received signal eye diagram of 4 symbol wide overlays



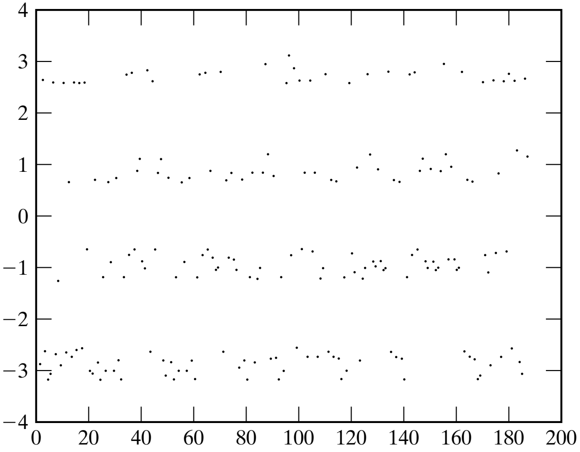
What if ... (cont'd)

Channel noise (cont'd): Pulse correlator filter synchronized output signal



What if ... (cont'd)

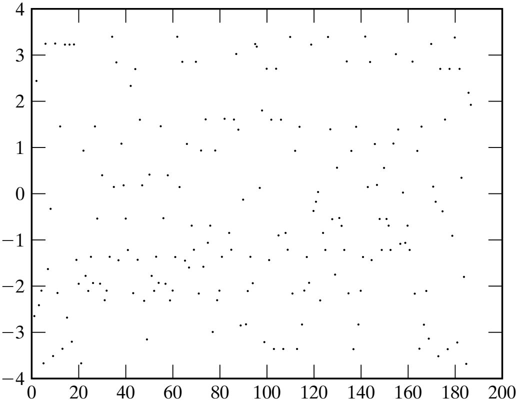
Multipath: Mild multipath soft decisions



The appearance of 4 distinct stripes indicates no decision errors.

What if ... (cont'd)

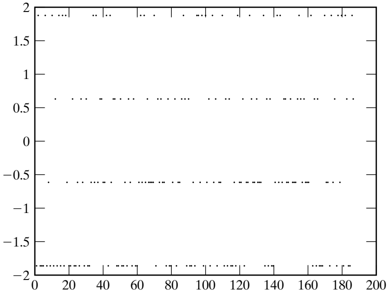
Multipath (cont'd): Harsh multipath soft decisions



The lack of emergence of 4 distinct stripes indicates the (likely) presence of decision errors.

What if ... (cont'd)

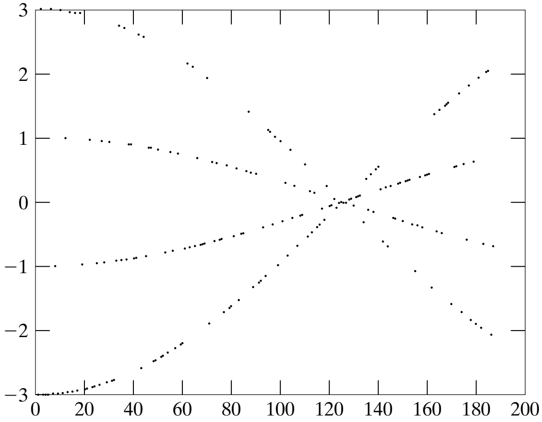
Carrier phase offset: Severe offset



- The attenuation due to carrier phase offset reduces all soft decisions below magnitude 2 resulting in no ± 3 as decision device outputs $\Rightarrow$ plenty of errors.
- If scaled back up so stripes of largest magnitude values are above magnitude 2, the SNR will suffer relative to case without carrier phase offset.

What if ... (cont'd)

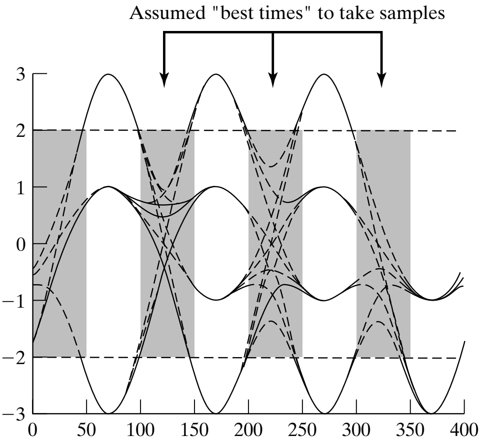
Carrier frequency offset: Soft decisions for 0.01% frequency offset



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

What if ... (cont'd)

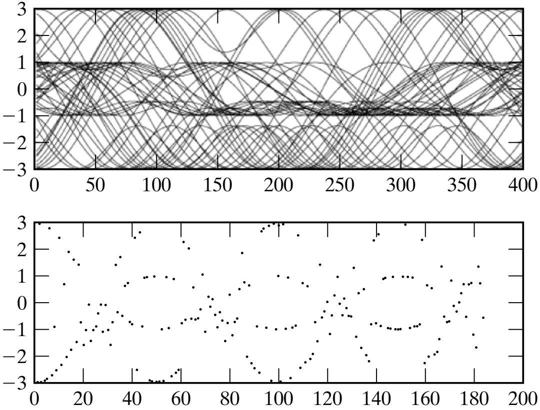
Downsampler timing offset: Eye diagram with debilitating offset



With samples for symbol values taken every 100 samples after sample 125, numerous errors occur.

What if ... (cont'd)

Downsampler period offset: Eye diagram (top) and soft decisions (bottom) with 1% downsampler period offset



All is lost...

Coming Attractions

- Coding and matched receive filtering are intended to counter effects of broadband channel noise.
- Equalization compensates for multipath interference, and can reject narrowband interferers as well.
- Carrier recovery schemes (including phase locked loops and Costas loops) adjust receiver oscillator phase to counteract phase offset and mild frequency offset.
- Timing recovery (using interpolation) is intended for reduction of downsampler timing and period offsets.
- Just as in the preceding impairment examples, we will consider one isolated impairment, and its fix, at a time. We will put them all together in the final project...

NEXT... We enter the adaptive layer and concoct various carrier recovery schemes.