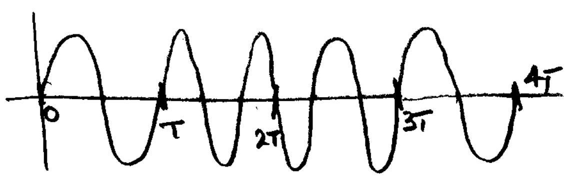
6.4 Signals With Memory | P+S 7.1.4

- So far, our model has been an independent selection of bits with every symbol. Sometimes, though, the amplitude, or even the pulse shape, can depend on what was transmitted previously. This memory can be inherent or designed in. In this sub section
  - some examples
  - simple sub optimum detectors.

Next subsection: optimum detection.

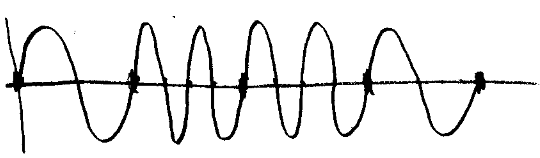
- FSK has inherent memory, depending on the modulation index.

modulation index $h = \Delta f \cdot T$

- 

$\leftarrow h = \frac{1}{2} = \left(\frac{3}{2T} - \frac{1}{T}\right)T$

Any symbol of odd # of half-cycles reverses the starting phase.

- 

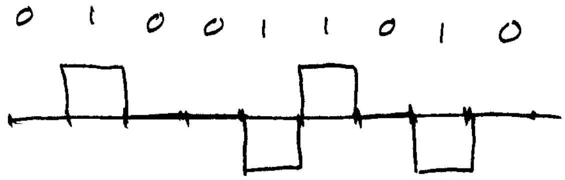
$\leftarrow h = \left(\frac{2}{T} - \frac{1}{T}\right)T = 1$

no memory

- high speed paging by R.FLEX (Motorola). Frequencies are -2400 Hz, -800 Hz, 800 Hz, 2400 Hz, at 4800 sym/sec

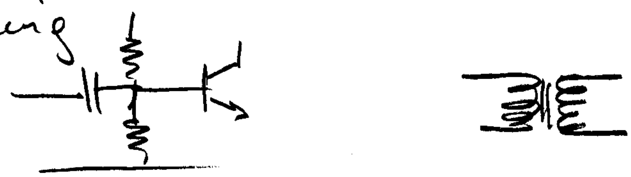
$h = \frac{\Delta f}{R_s} = \frac{1600}{4800} = \frac{1}{3}$ Memory

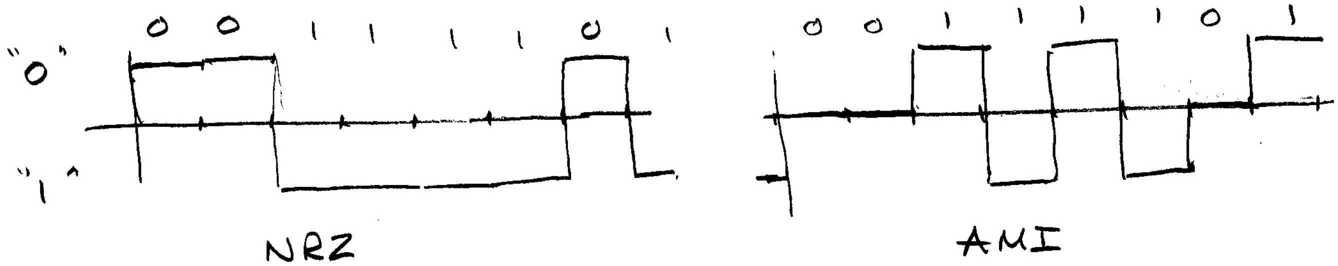
- Alternate Mark Inversion (AMI), also known as bipolar, is a "pseudo ternary" method.



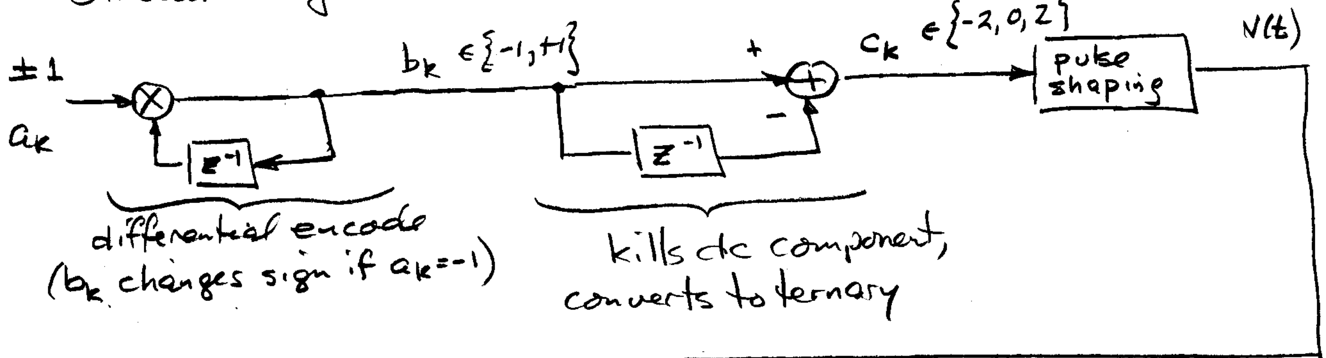
logic '1' sent with alternating polarity +1, −1

Why? Because it has no dc component and can therefore get through capacitor or transformer coupling

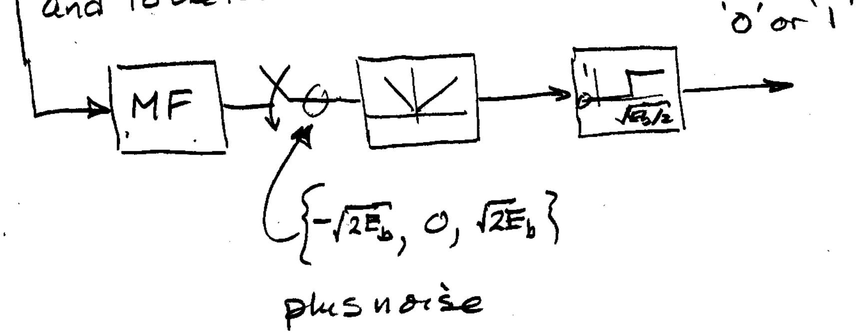




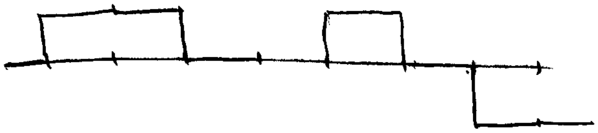
Circuit to generate:



and to detect

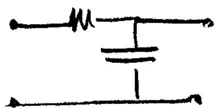


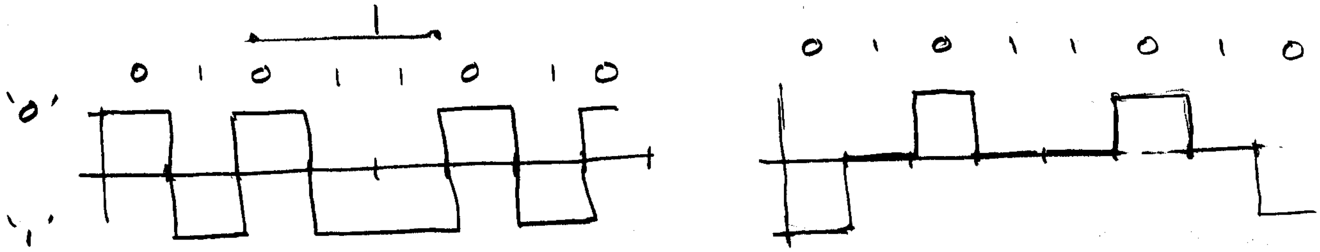
- Duobinary. Another pseudo ternary coding, this one cuts high frequencies, to facilitate transmission through low pass channels



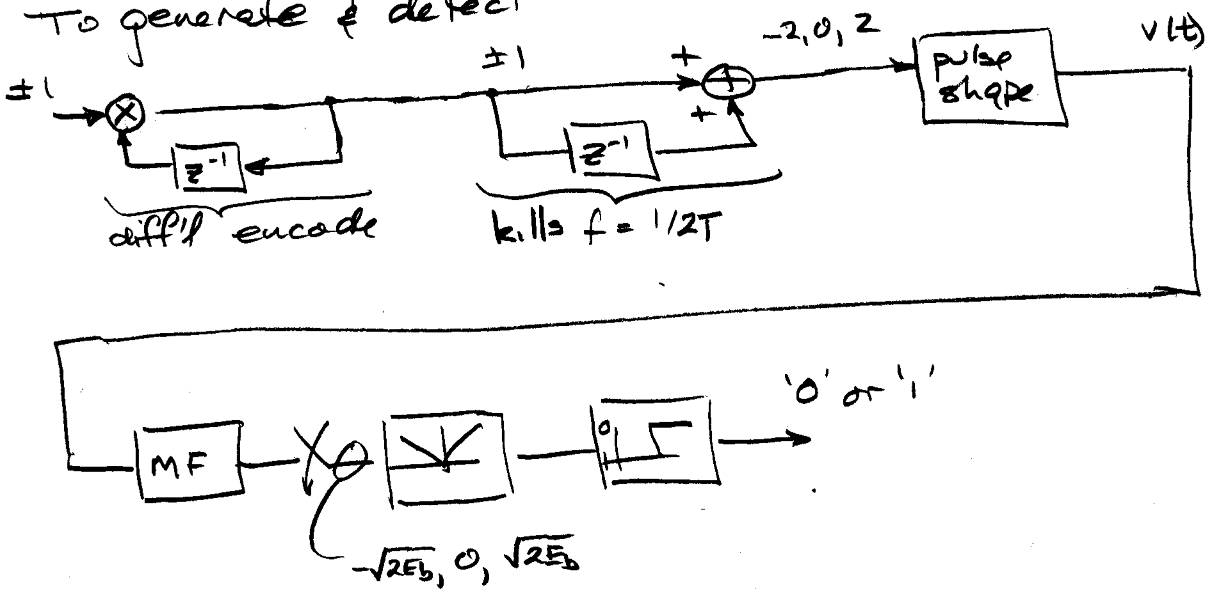
logic '0' sent with +1, −1 levels
logic '1' with zero level
Always at least one zero level between +1, −1 level change.
No oscillation +1, −1, +1, −1 allowed

Why? Low pass circuit



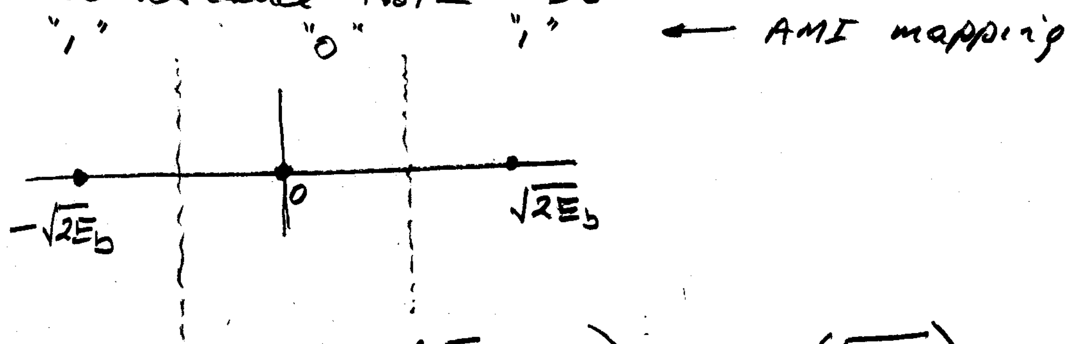


To generate & detect



- Also see Miller codes P+S p 461

- Error rate of this suboptimum detector:
  - MF output has $s = -\sqrt{2E_b}, 0, \sqrt{2E_b}$ and noise variance $N_0/2$, so



$$Pr[err|"0"] = 2Q\left(\frac{\sqrt{2E_b}}{2\sqrt{N_0/2}}\right) = 2Q(\sqrt{\gamma_b})$$

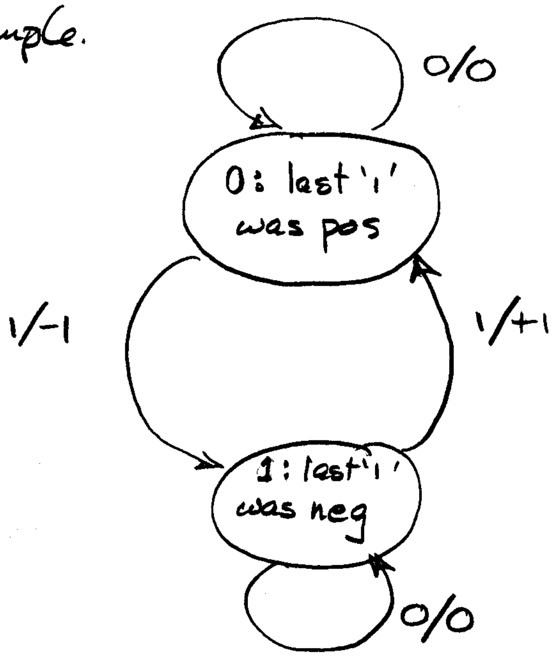
$$Pr[err|"1"] = Q(\sqrt{\gamma_b}) - Q\left(\frac{3}{2}\frac{\sqrt{2E_b}}{\sqrt{N_0/2}}\right) = Q(\sqrt{\gamma_b}) - Q(3\sqrt{\gamma_b})$$
$$\approx Q(\sqrt{\gamma_b})$$

$$P_b = \frac{1}{2}\left(Pr[err|"0"] + Pr[err|"1"]\right) = \frac{3}{2}Q(\sqrt{\gamma_b})$$

- We have paid heavily for the spectral properties
  - it's 3 dB poorer than binary antipodal
  - <u>and</u> twice the peak power of bin antip

- Note that detector does not account for memory. It allows $+\sqrt{2E_b}, +\sqrt{2E_b}$ in succession for AMI and $+\sqrt{2E_b}, -\sqrt{2E_b}$ in duobinary

- Describe by a state diagram. Use AMI as an example.



With only two states, it is simple.

labels:

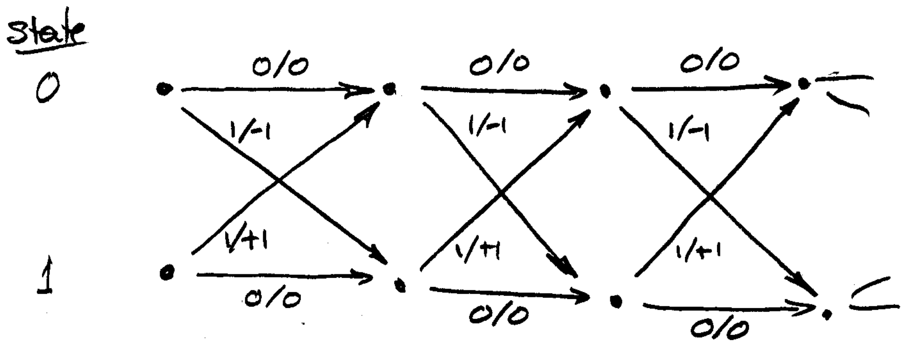
logic in / ternary level out

An FSM with random transitions is a Markov chain.

If you know the state sequence, you know the data.

Transmitted amplitude of symbol k is determined by the transition state(k-1), state(k).

- The state diagram is often unrolled as a trellis



A candidate sequence is a path through the trellis.

By convention, start in a known state (e.g. state 0)