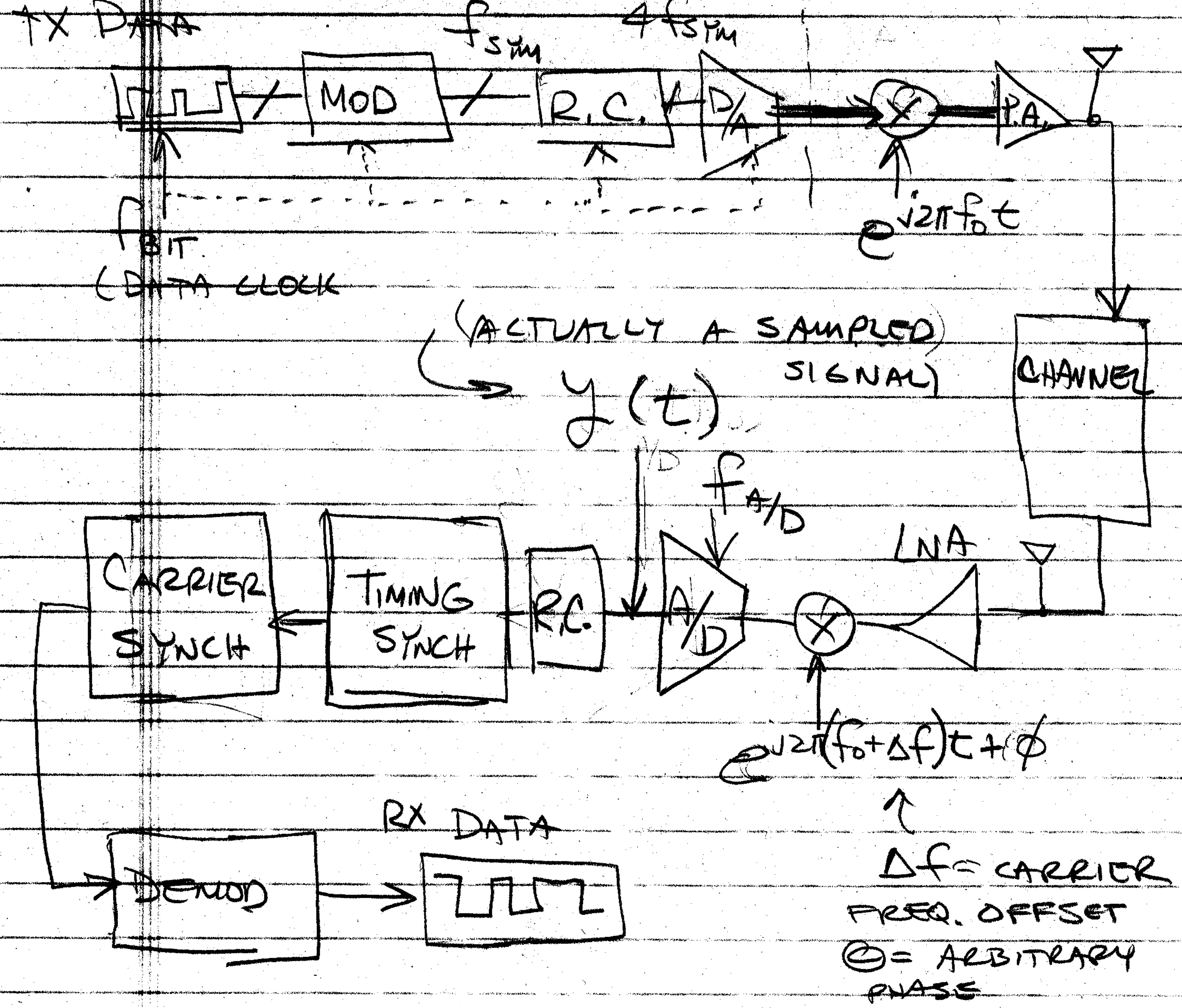
(SEE H. MEYR BOOK)
ALSO PAPERS ON WEB

SYNCHRONIZATION



TIMING SYNCH: RECOVERS THE SYMBOL CLOCK, f_{SYM} WHICH INDIRECTLY IS THE ORIGINAL DATA CLOCK f_{BIT}

CARRIER SYNCH: RECOVERS THE PHASE & CARRIER FREQUENCY

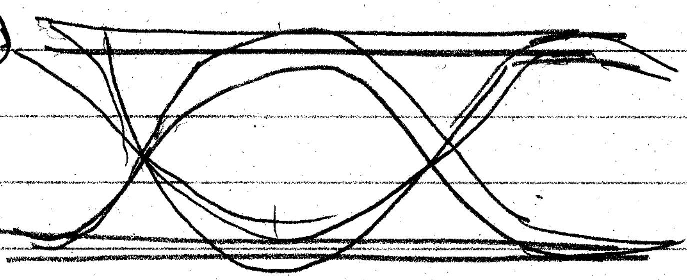
WHAT IS NEEDED IN $Y(t)$ TO BE ABLE TO PERFORM TIMING SYNCH?

1) PERIODIC:
e.g. $y(t) = y(t + n\,T_{sym})$ WITH A PERIOD RELATED TO THE SYMBOL RATE

2) KNOWN: IT IS A PILOT SEQUENCE KNOWN TO THE RECEIVER SO THAT A MATCHED FILTER CAN BE USED.

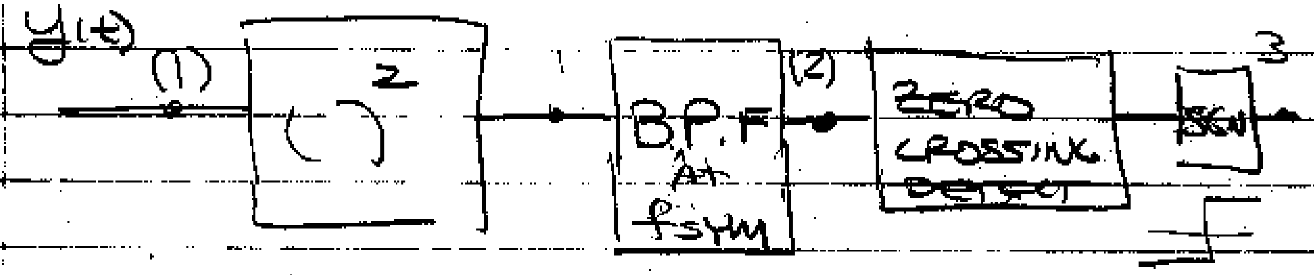
3) CYCLOSTATIONARY:
A WEAKER CONDITION WHICH JUST REQUIRES SOME MOMENT eg. $E(y(t)\,y(t+\tau))$ TO BE PERIODIC

LETS ASSUME ONLY (3) CYCLOSTATIONARITY
RECEIVED DATA EYE DIAGRAM (BPSK) (ASSUME CHANNEL IMPAIRMENTS ARE SMALL)

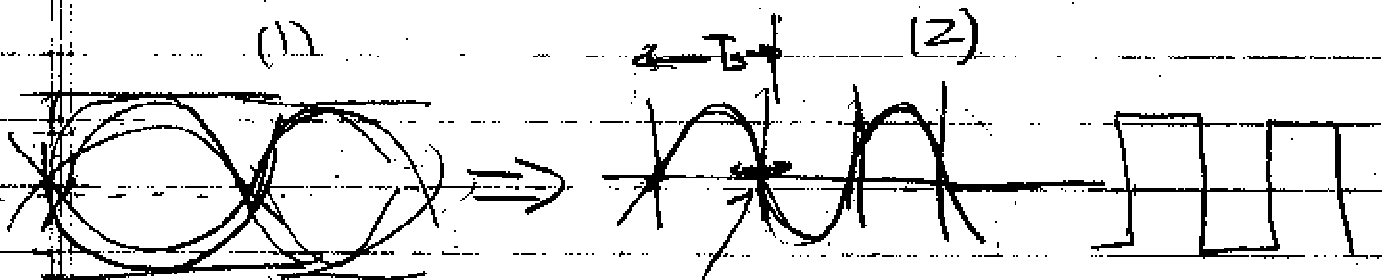


LOOKS STATIONARY (CYCLO-STATIONARY)

ONE STRATEGY IS TO USE A NON-LINEAR FUNCTION e.g. SQUARE



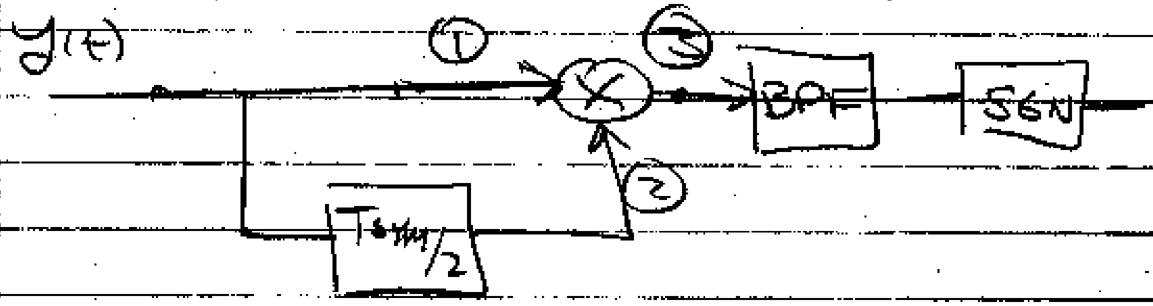
FOLLOWED BY A BAND PASS FILTER AND ~~ZERO~~ CROSSING DETECTOR

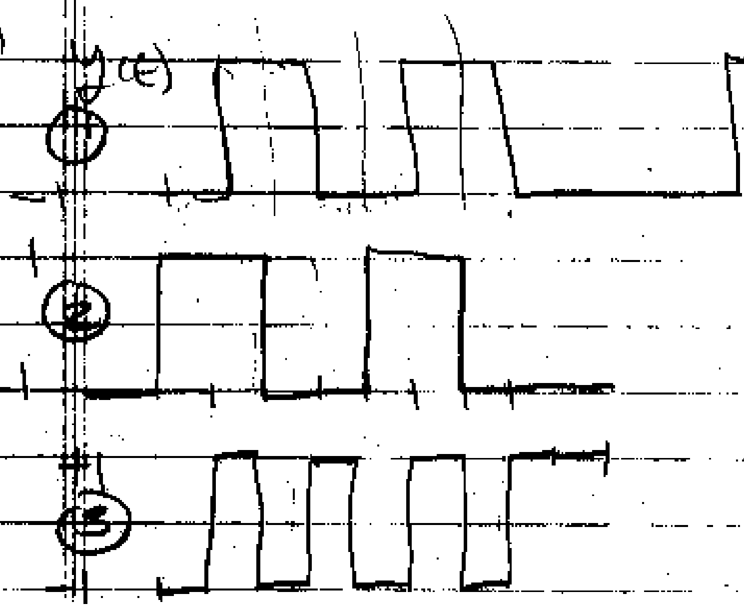


THERE WILL BE JITTER DUE TO THE DATA VARIATIONS

ANOTHER STRATEGY IS TO USE A PHASE LOCKED LOOP INSTEAD OF THE B.P.F

ANOTHER METHOD IS ~~TO~~ SIMPLY DELAY THE SIGNAL BY $T_{SYM}/2$

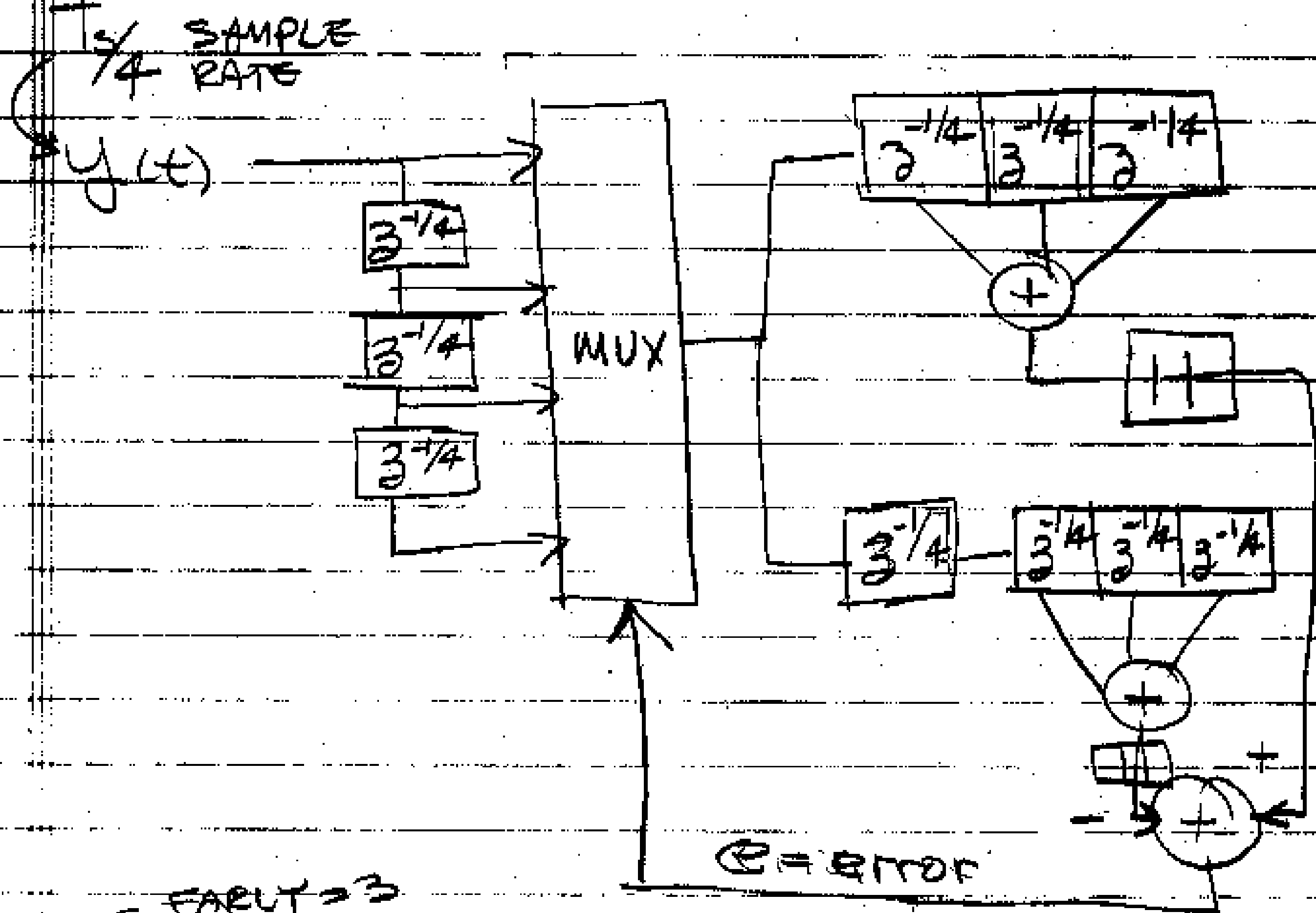


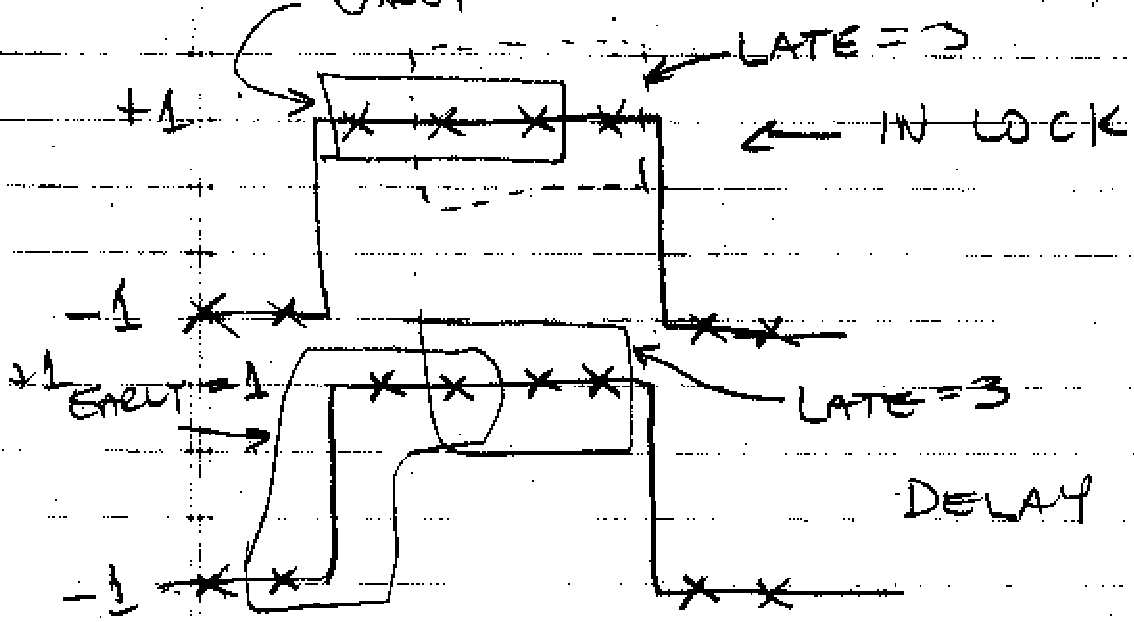


MORE POWER AT THE SYMBOL RATE

THESE ARE OPEN LOOP TECHNIQUES. THERE ARE CLOSED LOOP APPROACHES AS WELL

CLOSED LOOP - USE EARLY-LATE CORRELATOR BUT ONLY FOR EACH SYMBOL





DELAY INPUT USING MUX.

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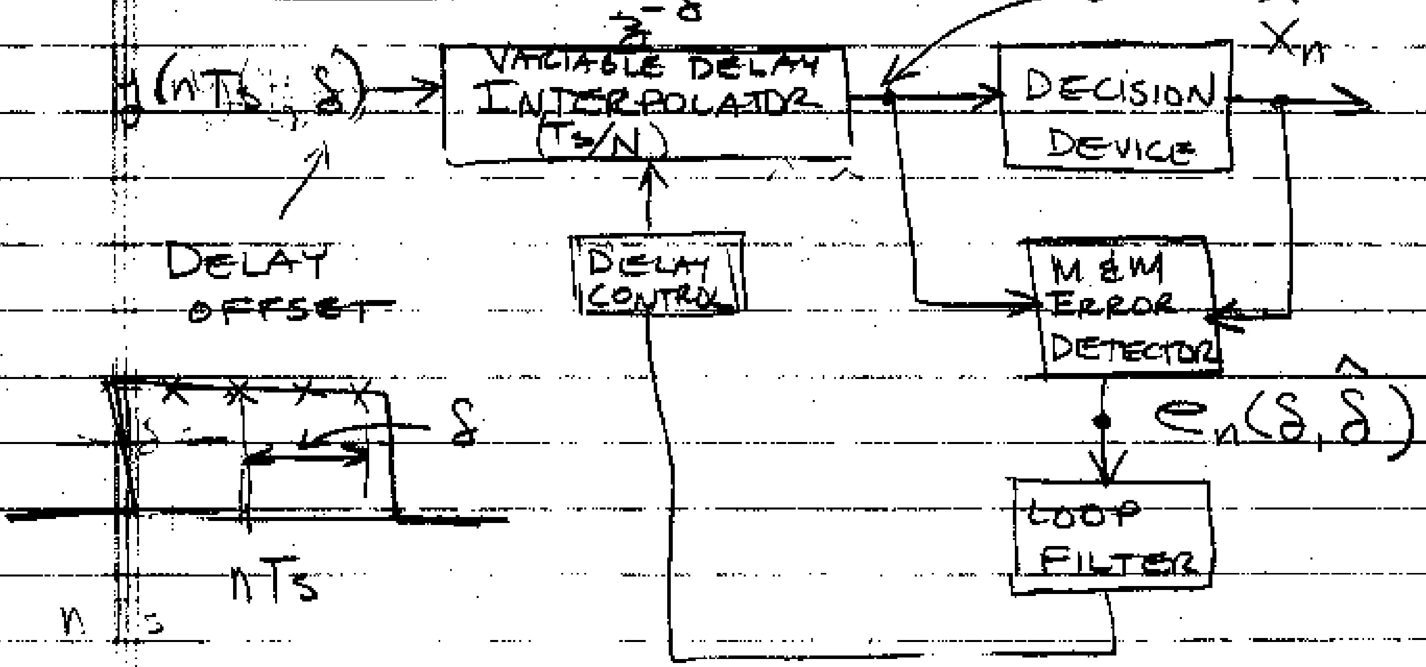
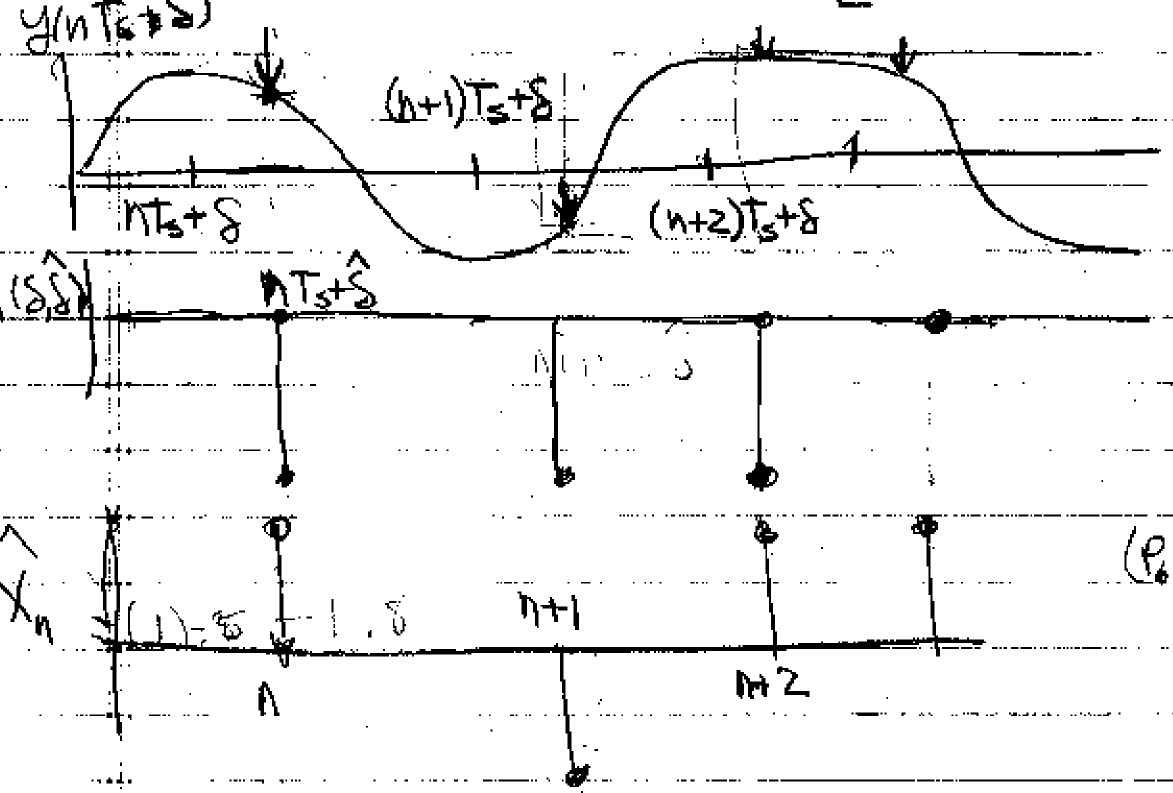
M & M SYNCHRONIZER

2 SAMPLES & DECISION DIRECTED



$$e_n(\delta,\hat{\delta}) = \hat{X}_{n-1}\, y(nT_s+\hat{\delta}, \delta) - \hat{X}_n\, y[(n-1)T_s+\hat{\delta}, \delta]$$



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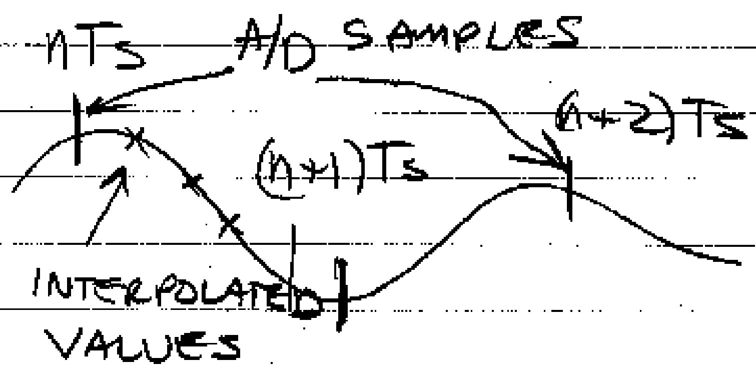
HOW DO WE DO ~~THE~~ INTERPOLATION?

THE INTERPOLATOR COMPUTES INTERMEDIATE POINTS BETWEEN SAMPLES SO WE DON'T HAVE TO HAVE THE A/D ~~OPERATE~~ AT THE INTERPOLATED RATE

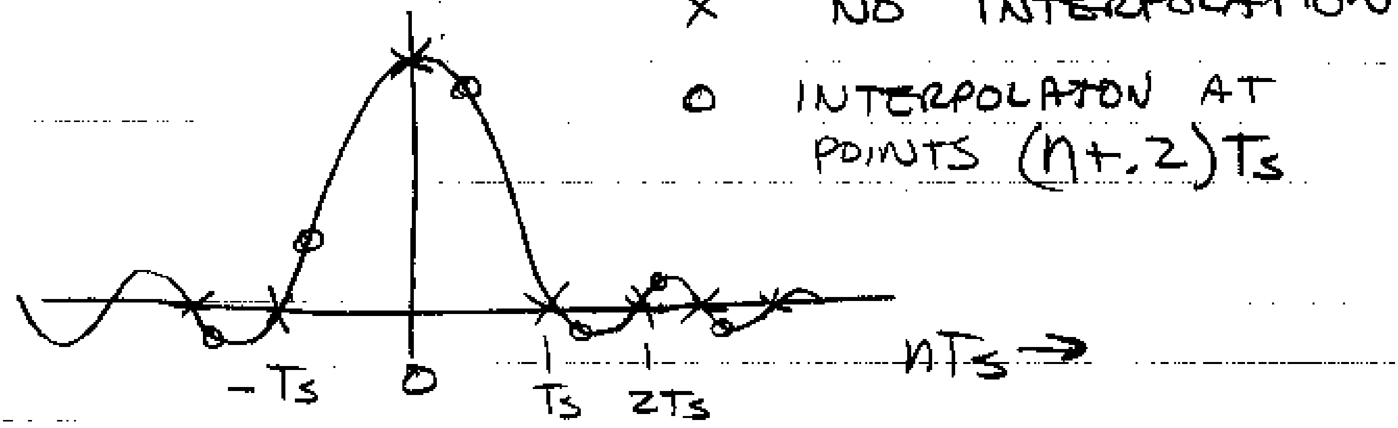


IF A SIGNAL IS BANDLIMITED TO $\frac{1}{2T_s}$ THEN THE IDEAL INTERPOLATOR IS GIVEN BY

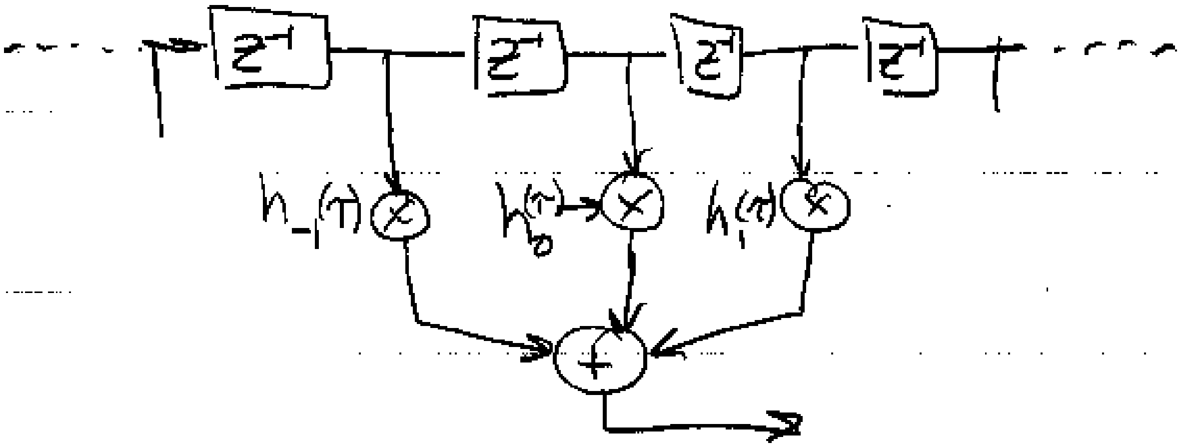
ARBITRARY DELAY

$$x(kT_s+\tau) = \sum_{n=-\infty}^{\infty} x(nT_s) \frac{\sin\left[\frac{\pi}{T_s}(kT_s+\tau-nT_s)\right]}{\frac{\pi}{T_s}(kT_s+\tau-nT_s)}$$

WHICH IS JUST AN FIR FILTER WITH $\frac{\sin X}{X}$ IMPULSE RESPONSE



SO WE COULD BUILD AN INTERPOLATOR USING AN FIR FILTER WHICH HAS VARIABLE COEFFICIENTS.



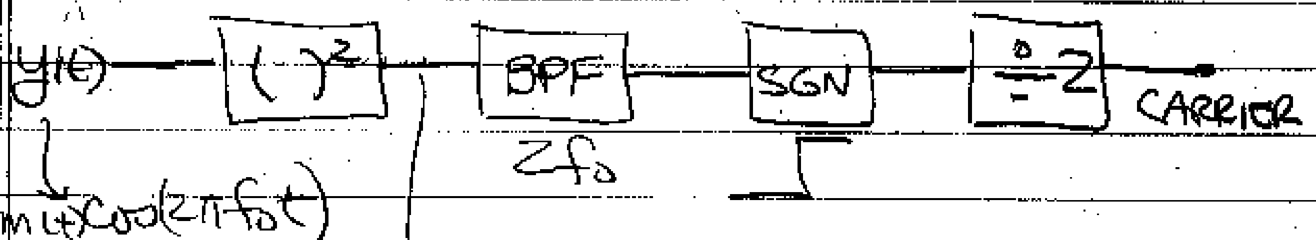
THIS IS A BIT BRUTE FORCE (REQUIRED ∞ NO OF TAPS) SO CAN WE DO IT WITH A SMALLER NUMBER OF TAPS

WE CAN USE A MUCH SHORTER FILTER (4-8 TAPS) AND USE A MMSE CRITERIA TO APPROXIMATE THE IDEAL FILTER.

WE COULD THEN STORE THOSE VALUES IN A TABLE OR JUST IMPLEMENT PARALLEL FILTERS.

CARRIER SYNCHRONIZATION

AGAIN CAN USE SQUARING STRATEGY TO FIND THE CARRIER FREQUENCY AND ITS PHASE.



$$\to \underbrace{m^2(t)}_{1}\ \underbrace{\cos^2(2\pi f_0 t)}_{1+\cos(2\pi\, 2f_0 t)}$$

$m(t) = \pm 1$

THIS HOWEVER RESULTS IN CIRCUITS THAT OPERATE AT $2f_0$ .. SO IT IS AN ANALOG SOLUTION – HOW TO DO IT DIGITALLY?

$$\boxed{\Theta = 2\pi\Delta f t + \phi}$$

$$y_n e^{-j\Theta} \Rightarrow \otimes \Rightarrow \sum_n \hat{a}_n^* y_n e^{-j\Theta} = e^{-j\Theta} \sum_n |A_n B_n|$$

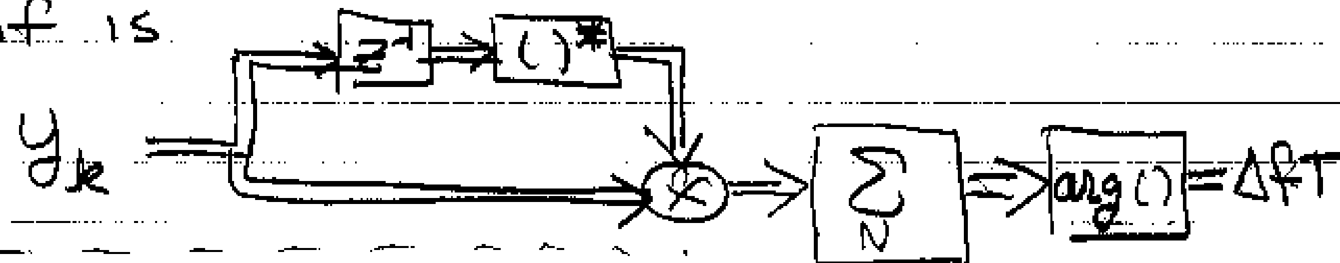
$\hat{a}_n^*$ (FROM DECODER)

$a_n = A_n e^{j\phi_n}$

$y_n = B_n e^{j\phi_n}$

WE CAN ISOLATE THE PHASE ERROR, Θ

A STRAIGHTFORWARD WAY TO ESTIMATE Δf IS



$$\sum_N y_k y_{k-1}^* = e^{j2\pi\Delta f T_s} \sum_N |A_k A_{k-1}|$$

WHERE $y_k = A_k e^{j(\phi_k + 2\pi\Delta f k T_s + \theta)}$

THE PROBLEM IS THAT FOR SMALL FREQUENCY OFFSETS $\Delta f T_s$ IS VERY HARD TO ESTIMATE

e.g. 10 ppm DIFFERENCE BETWEEN THE TRANSMITTER & RECEIVER

$$5\text{ GHz} \times 10^{-5} = 5\times10^{9}\times10^{-5} = 5\times10^{4}\text{ Hz}$$

LET T_s BE $.1\,\mu s = 10^{-7}$ sec

$$\Delta f T_s = 5\times10^{4}\times10^{-7} = 5\times10^{-3}$$

IN DEGREES

$$5\times10^{-3}\times 360 = \underline{1.8^\circ}$$

PHASE NOISE IS COMPARABLE!