L15 Bandpass Detection

15.1 Coherent Detection of BPSK

- ~~Bas~~ Detection of passband signals essentially identical to the baseband case

- Use correlator or MF to map the received signal to $z(T)$ and make a decision

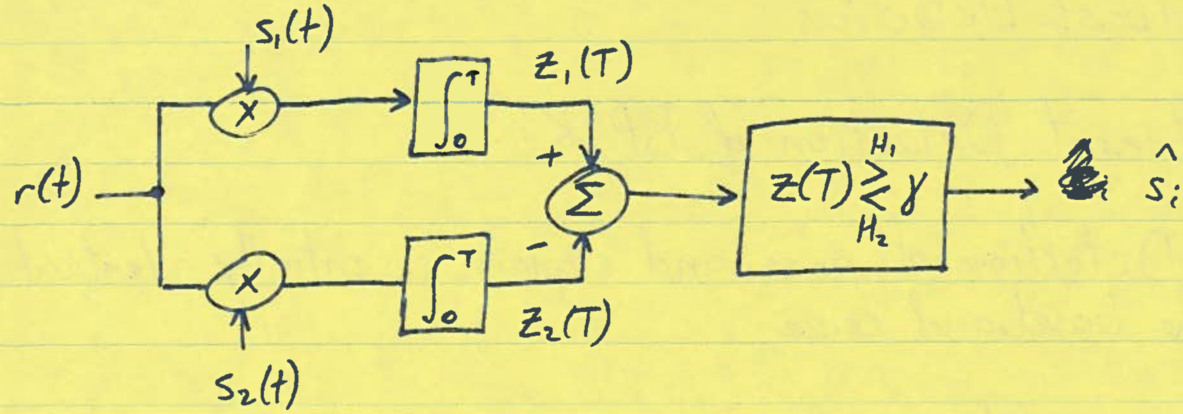
- What about the "coherent" part of the title? It means that you need to correctly align the phase of your matching signal ~~to~~ (i.e. in the receiver) to the phase of your incoming carrier. (~~that~~ the one that just flew through the channel into your receiver) ... more on this in a moment

- For BPSK

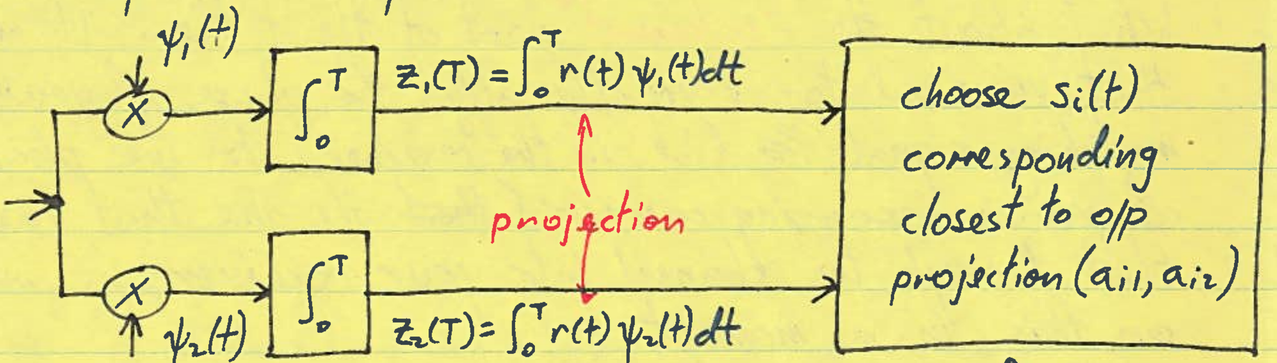
$$s_1(t) = \sqrt{\frac{2E}{T}} \cos(\omega_0 t + \phi) \qquad 0 \leq t \leq T$$

$$s_2(t) = \sqrt{\frac{2E}{T}} \cos(\omega_0 t + \phi + \pi) = -\sqrt{\frac{2E}{T}} \cos(\omega_0 t + \phi)$$

- as with baseband we can detect the digital information in these with ...



- more generally we can express this in terms of the signal space concept



closest means $\underset{\bar{s}_i}{\arg\min}\,(\bar{s}_i - \bar{z}_i(T))^2$

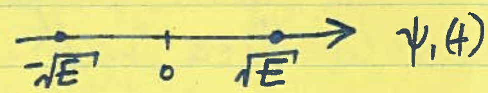
recall: $a_{ij} = \int_0^T s_i(t)\,\psi_j(t)\,dt$

projection of ith signal on jth basis

- for BPSK $\psi_1(t) = \sqrt{\dfrac{2}{T}} \cos \omega_0 t \qquad 0 \le t \le T$

$$a_{11} = \int_0^T s_1(t)\,\psi_1(t)\,dt = \sqrt{E}$$

$$a_{21} = \int_0^T s_2(t)\,\psi_1(t)\,dt = -\sqrt{E}$$



note: the effectiveness of this scheme is undermined if the phases of s_i & ψ_1 are not aligned

e.g. if ψ_1 is as before and $s_1 = \sqrt{\frac{2E}{T}} \cos\left(\omega_o t + \frac{\pi}{2}\right)$

$$s_2 = -\sqrt{\frac{2E}{T}} \cos\left(\omega_o t + \frac{\pi}{2}\right)$$

now $a_{11} = a_{21} = \phi$! that's a big problem and hence requires some phase synchronization scheme

15.2 Coherent Detection of Multiple Phase-Shift Keying

- The natural progression from BPSK

$$s_i(t) = \sqrt{\frac{2E}{T}} \cos\left(\omega_o t - \frac{2\pi i}{M}\right) \quad 0 \le t \le T \quad i = 1, \ldots, M$$

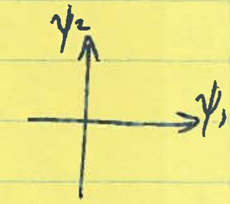
- Do we need an RX with M correlators ?!?!

- No! Just 2 if we exploit concepts from the signal-space perspective

- recall the basis functions we previously discussed with regards to M-ary PSK

$$\psi_1(t) = \sqrt{\frac{2}{T}} \cos \omega_o t \qquad \psi_2(t) = \sqrt{\frac{2}{T}} \sin \omega_o t$$

"in-phase" "quadrature"

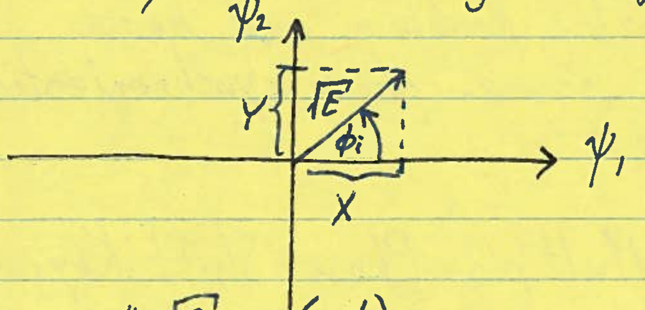


· allowing us to express

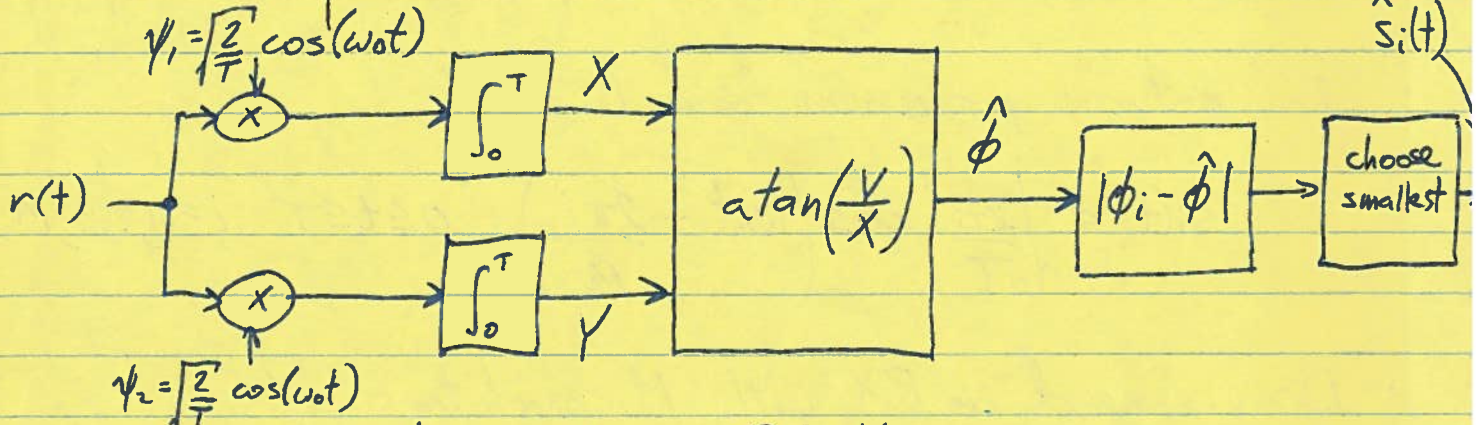
$$s_i(t) = a_{i1}\,\psi_1(t) + a_{i2}\,\psi_2(t)$$

$$= \underbrace{\sqrt{E}\cos\left(\frac{2\pi i}{M}\right)\psi_1(t)}_{\text{projection on } \psi_1 \text{ axis}} + \underbrace{\sqrt{E}\sin\left(\frac{2\pi i}{M}\right)\psi_2(t)}_{\text{projection on } \psi_2 \text{ axis}}$$

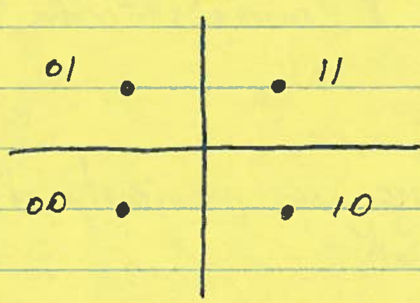
$r(t)$, my received signal (ignoring noise) looks like ...

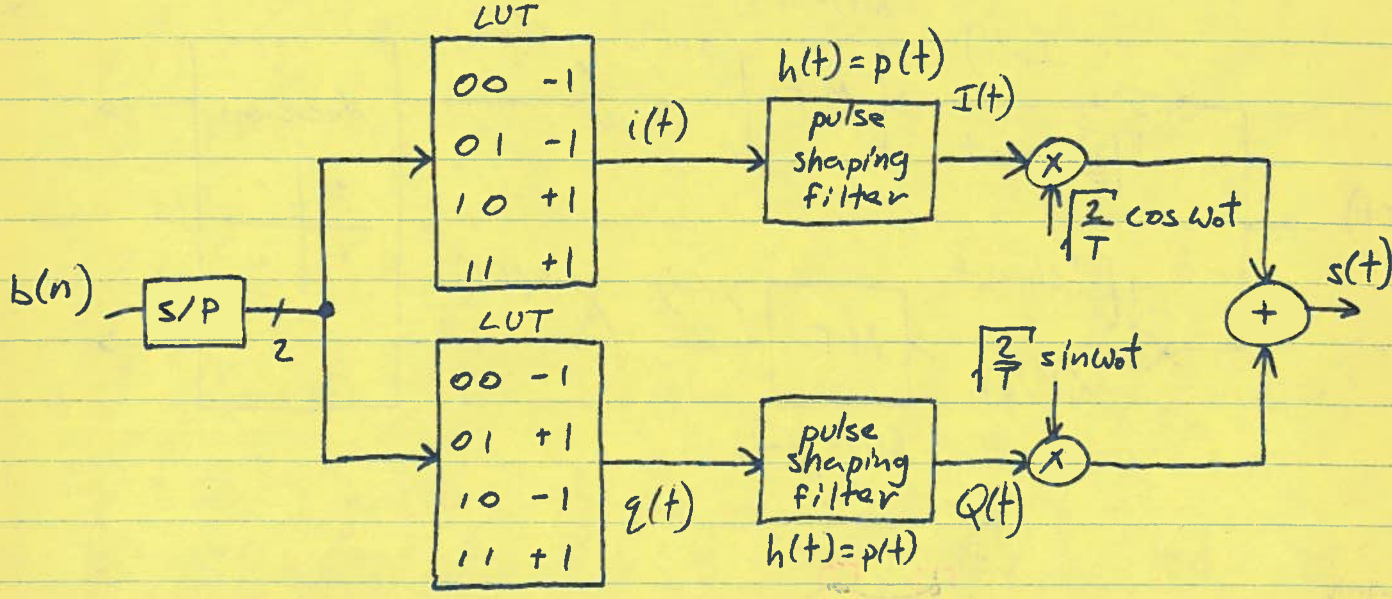


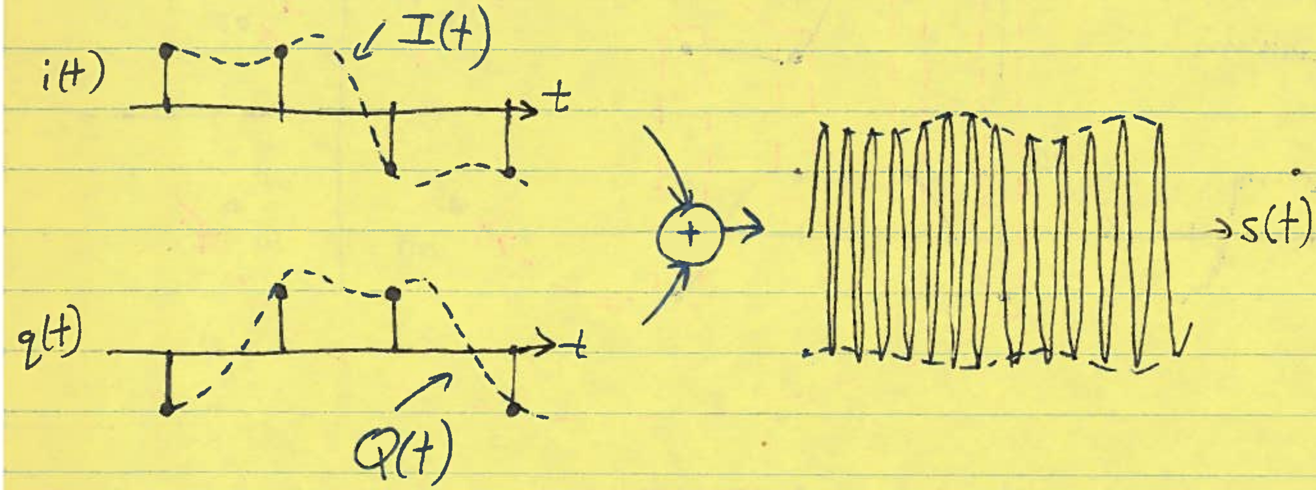
X & Y are projections (i.e. my a_{ij}'s)



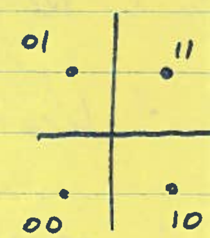
a common variant is $M=4$ QPSK



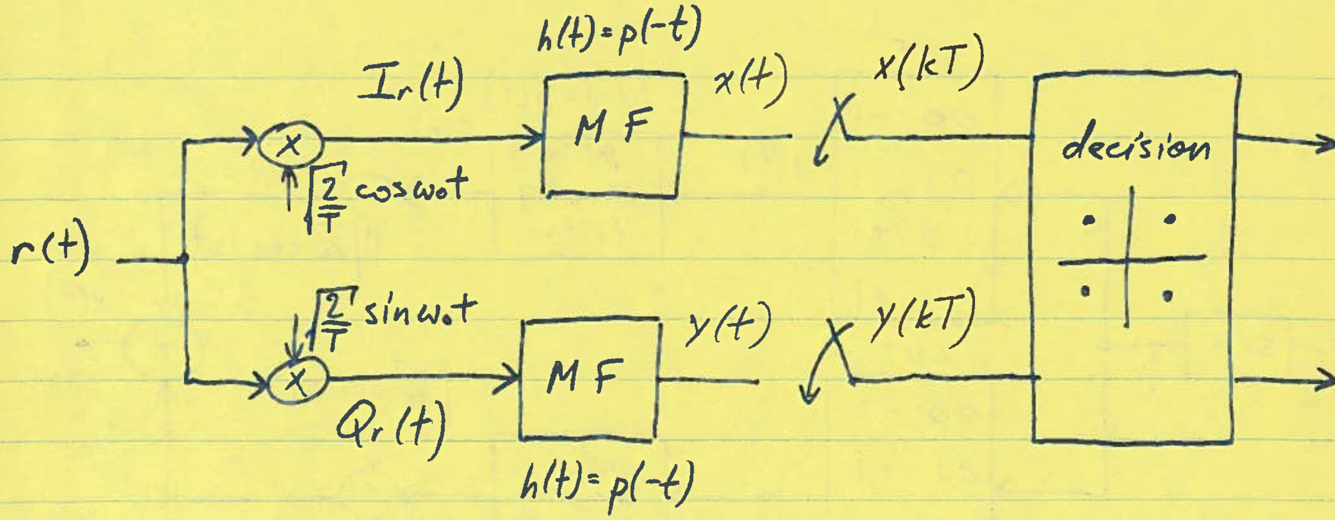


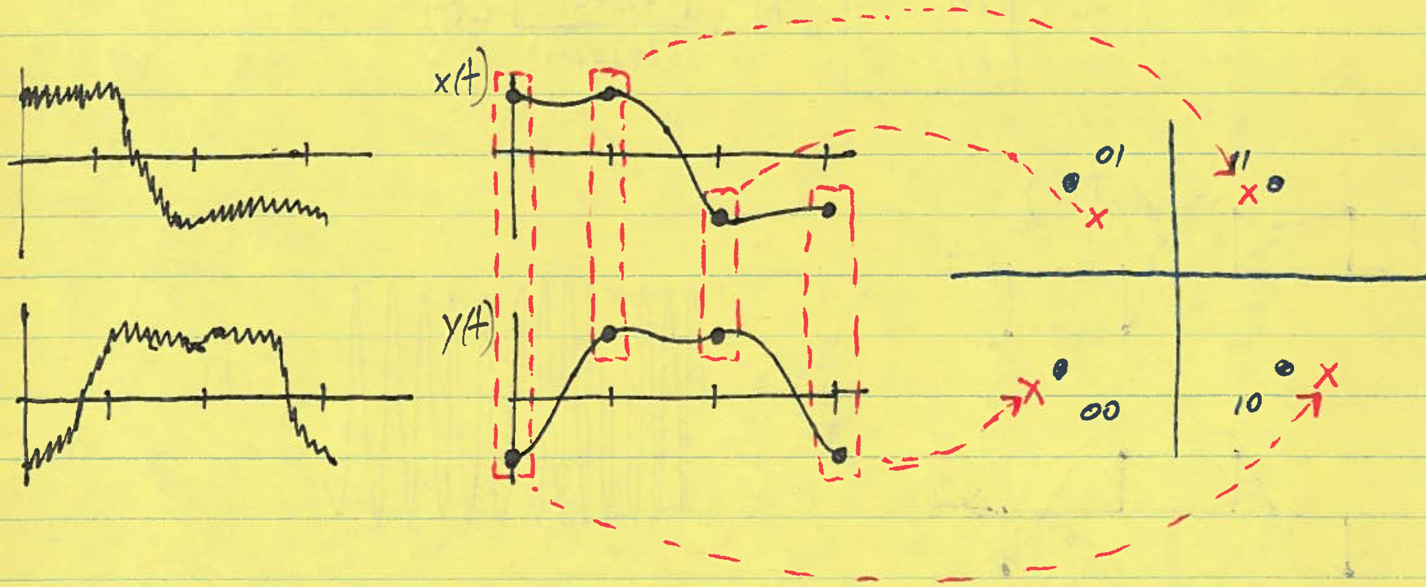


n	0	1	2	3	4	5	6	7
$b(n)$	1	0	1	1	0	1	0	0
k		0		1		2		3
$a_1(k)$		+1		+1		-1		-1
$a_2(k)$		-1		+1		+1		-1



and the receiver...





15.3 Noncoherent Detection of DPSK

- We can get by without necessarily knowing the phase

in general: $s(t) = \sum_k A\,p(t-kT)\cos(\omega_0 t + \theta_k)$

$$\theta_k = \operatorname{atan}\left(\frac{a_1(k)}{a_2(k)}\right)$$ in phase / quadrature ← phase ↔ data map

e.g. $\theta_k = 0, \pi$ in BPSK

$\theta_k = \pi/4,\ 3\pi/4,\ 5\pi/4,\ 7\pi/4$ in QPSK

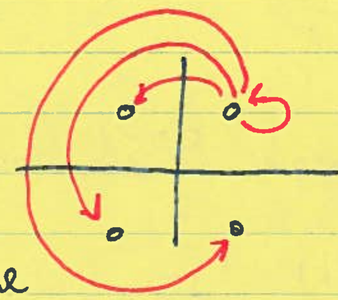
... instead of mapping data to phase ..

... map it to PHASE SHIFT

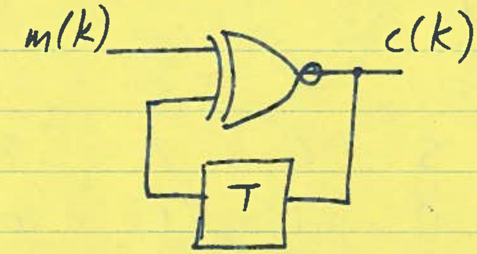
$$\theta_k = \theta_{k-1} + \Delta\theta_k$$

$\Delta\theta_k = 0, \pi$ in BPSK

$\Delta\theta_k = 0, \frac{\pi}{2}, \pi, \frac{3\pi}{2}$ in QPSK



- this is basically our differential line encoder again

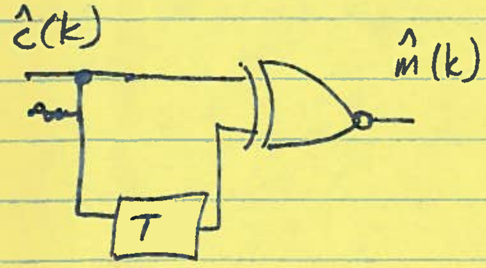


$m(k)$	$c(k-1)$	$c(k)$
0	0	1
0	1	0
1	0	0
1	1	1

if current i/p $m(k)$ & past o/p have same phase send a 1
if different phase send a 0

- can send $\bar{c}(k)$ as well,

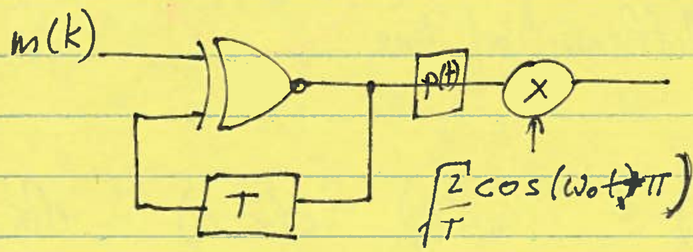
... decoder should look pretty familiar as well



$\hat{c}(k-1)$	$\hat{c}(k)$	$\hat{m}(k)$
0	0	1
0	1	0
1	0	0
1	1	1

if there's no difference between the last two bits the info is a one

a simple BPSK looks like



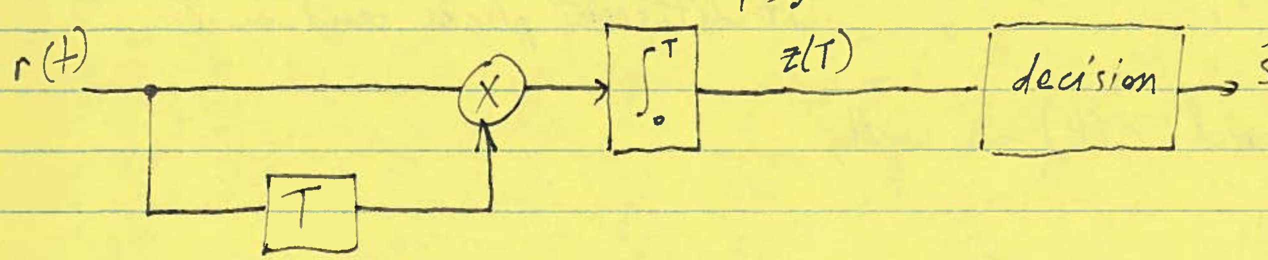
$\sqrt{\frac{2}{T}} \cos(\omega_0 t + \pi)$

k =	0	1	2	3	4	5	6	7	8
m(k)		1	1	0	1	0	1	1	0
c(k)	1	1	1	0	0	1	1	1	0
$\theta(k)$	π	π	π	0	0	π	π	π	0

$$\frac{2}{T}\int_0^T \cos(\omega_0 t + \pi)\cos(\omega_0 t + \pi)\,dt = +1$$

and the receiver is

$$\frac{2}{T}\int_0^T \cos(\omega_0 t)\cos(\omega_0 t + \pi)\,dt = -1$$

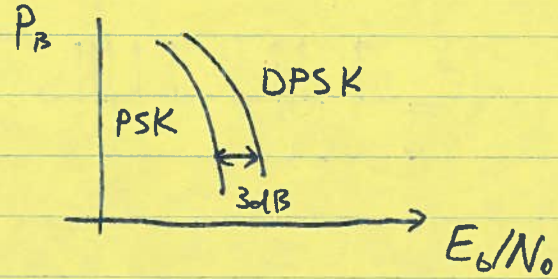


z(T) $\sqrt{E}$ $\sqrt{E}$ $-\sqrt{E}$ $+\sqrt{E}$ $-\sqrt{E}$ $\sqrt{E}$ $\sqrt{E}$

1 1 0 1 0 1 1

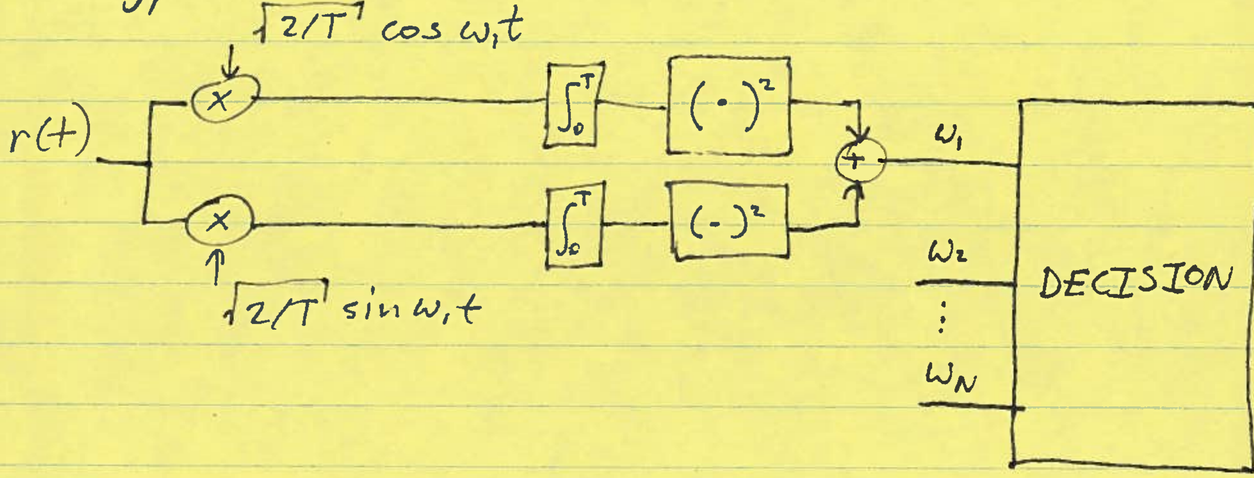
- in coherent signaling we demodulate the noisy received signal with a clean reference

- in DPSK we use a noisy reference as well so we have 2x the noise (i.e. signal + ref.) $\therefore$ we expect

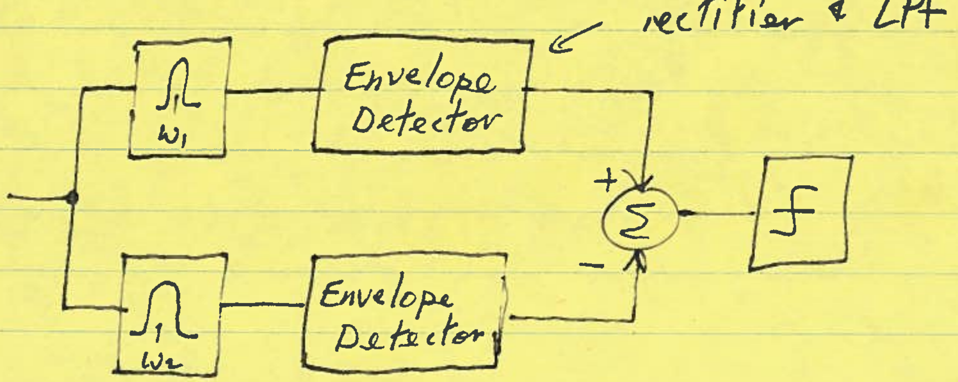


15.4 Noncoherent FSK

- Energy detector method



- envelope detectors



or even