Sending Digital Data (Chapter 7)

Two basic methods (plus variants ..)

① Line coding (7.2 - 7.7)

3-5 coach

Coding schemes to send the data directly, in baseband, over lines.

Used for serial lines (RS-232, ethernet)

(Next week) recording (magnetic, optical, etc).

② Carrier systems (7.8)

~~3-4 coach~~

5-9 coach

The digital data modulates a carrier

Used for wireless, and when it must be sent over an analog (audio?) channel.

(Today) modems.

Digital Carrier systems (7.8)

Take the digital data — use it as the baseband ($m(t)$) for any analog method (AM, DSB, QAM, FM, PM, etc...).

AM = "OOK" on-off keying

"ASK" amplitude shift keying.

"OOK":

Carrier is on for 1
off for 0

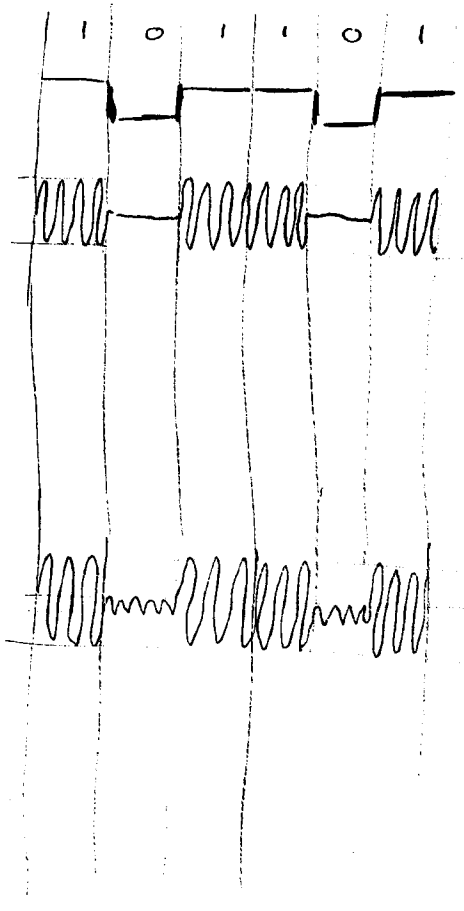
Advantages: simple!
efficient.

This is the original RF data transmission scheme using "Morse Code".

"ASK"

Carrier stays on for 0, but at a lower level

low level carrier for 0 keeps synchronous detectors in sync.



Demodulation of OOK, ASK

Usual method:

Envelope detector.

Traditional method for morse code:

Use a receiver designed for SSB, with oscillator $\approx$ 1 kHz away from f_c.

Then you can hear it.

For better performance:

Synchronous detection —

Use PLL to sync.

low level carrier in ASK keeps it in sync.

Rarely used — when you can afford the complexity, PSK or FSK works better.

FM, PM

= "FSK" = frequency shift keying

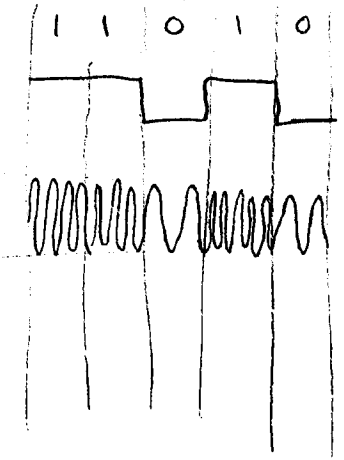
"PSK" = phase shift keying.

"DPSK" = differentially coherent phase shift keying.

FSK — use one frequency for 1 (f_{c1})

another frequency for 0 (f_{c0})

Think of it as 2 complementary OOK signals.



Actual method of generation:

Digital data into FM transmitter.

Usually the "shift" is specified

shift = $\Delta f = f_{c1} - f_{c2}$

Advantages: Noise immunity

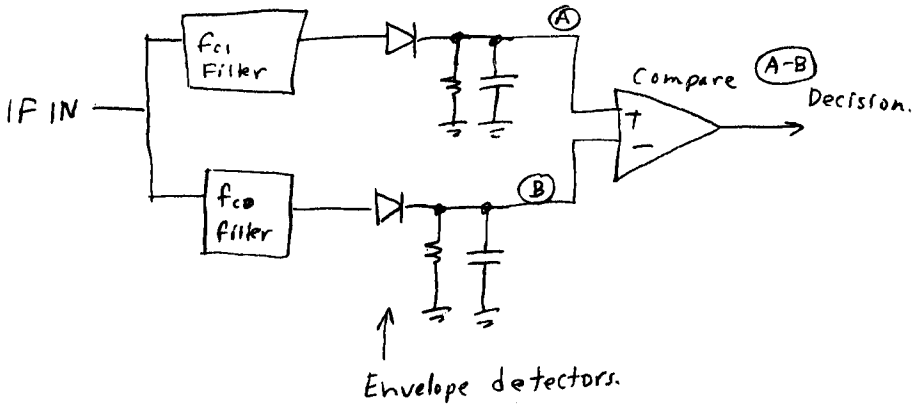
Disadvantages: Bandwidth (2X OOK)

Demodulation of FSK

Usual method:

2 filters with envelope detectors

The difference generates a polar signal.

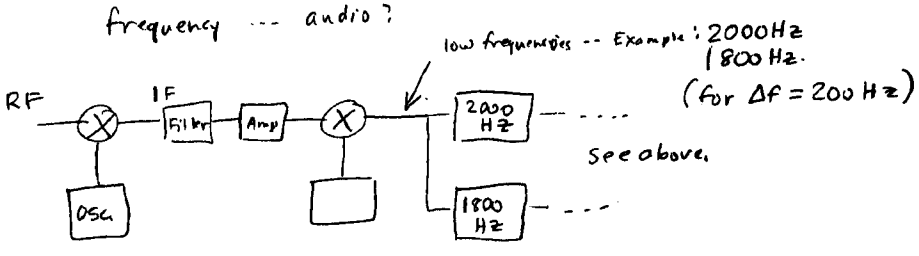


Signal at A should be the data.

B should be its complement

A-B has better (3dB) noise immunity.

Usually, these filters (f_{c1}, f_{c0}) are at a very low frequency ... audio?



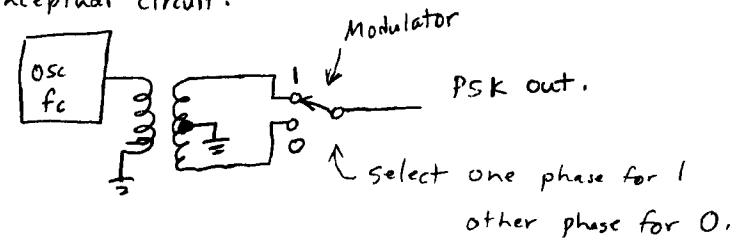
PSK

— Use the same frequency

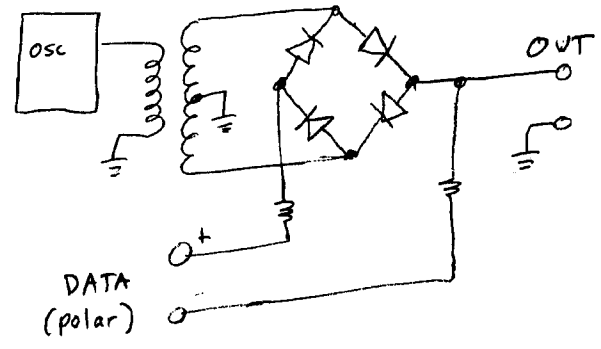
Change the phase.

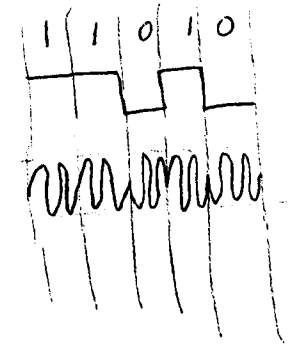
— usually this means invert the phase

conceptual circuit.



practical circuit





Advantages: Noise immunity

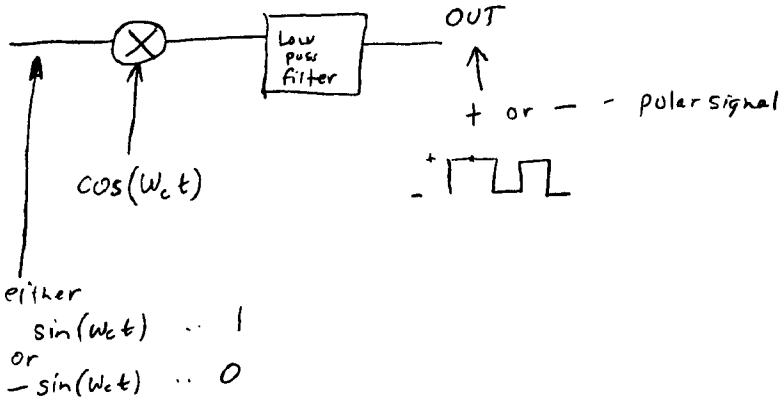
· Bandwidth (same as OOK)

Disadvantages: Need synchronous detection

Demodulation of PSK

Can't use envelope detection

Need phase reference, synchronous detection.



Need to identify which phase is which — possible reversal of 1 + 0.

Method: transmit phase reference.

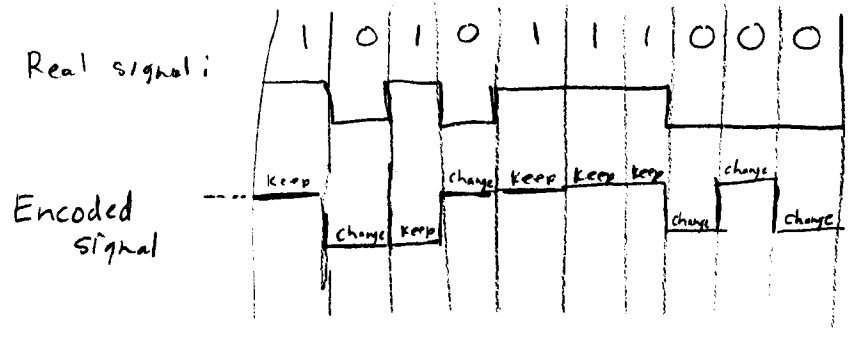
"Differentially coherent" PSK

PSK with changes---

Instead of transmitting 1 or 0 directly —

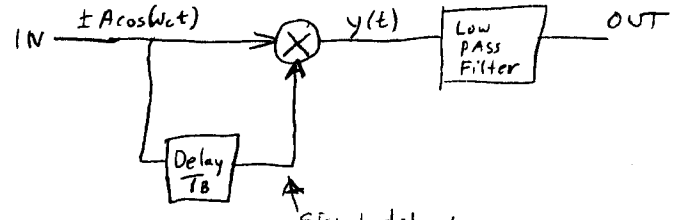
data = 1 ⇒ Keep the same state

0 ⇒ change the state



To decode: Same state ⇒ 1
change ⇒ 0

circuit:



Signal delayed one pulse — So it will have the phase of the previous one.

Same data = in phase ⇒ 1

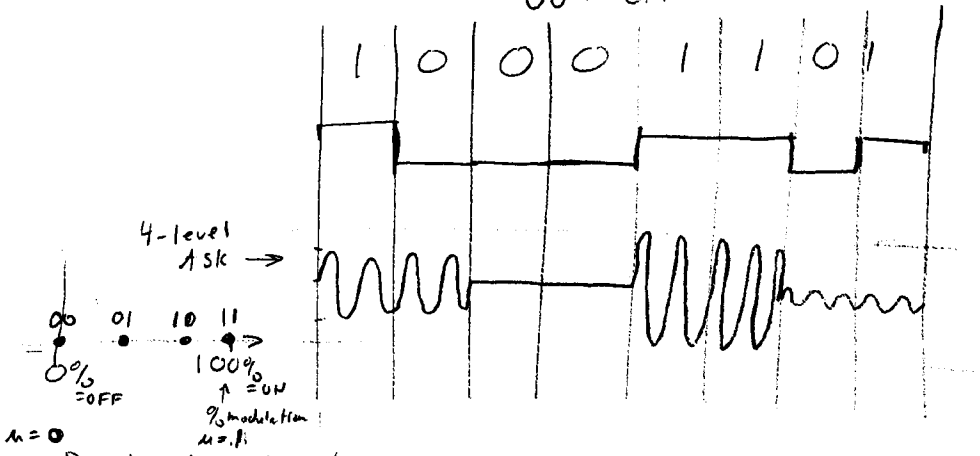
Change = out of phase ⇒ −1

Improving the data rate

ASK -- Use multiple levels

Example: 2 bits = 4 levels

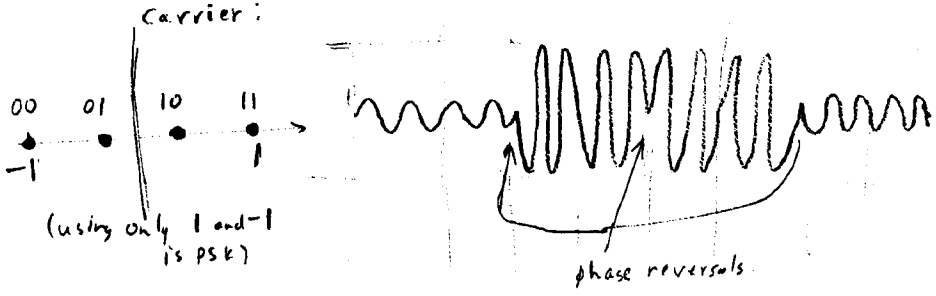
11 = 100%
10 = 67%
01 = 33%
00 = Off



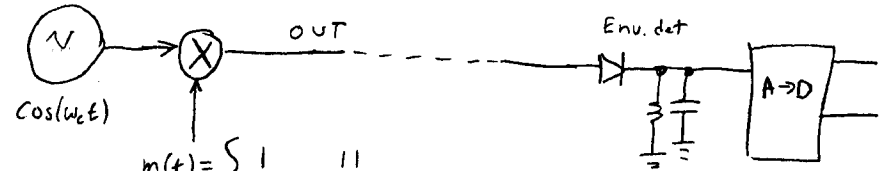
Disadvantages: degraded noise immunity.

# of levels is limited by noise

Using suppressed carrier:

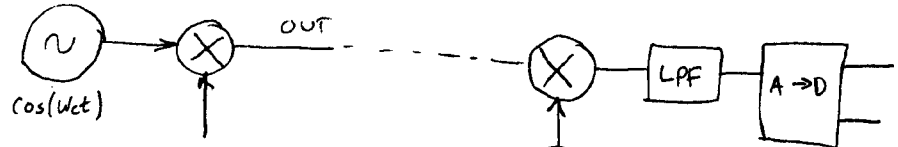


ASK



$$m(t) = \begin{cases} 1 & 11 \\ .67 & 10 \\ .33 & 01 \\ 0 & 00 \end{cases}$$

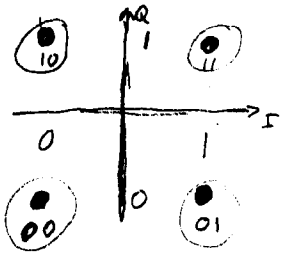
Using suppressed carrier



$$m(t) = \begin{cases} +1 & 11 \\ +.33 & 10 \\ -.33 & 01 \\ -1 & 00 \end{cases}$$

Another way is to use QAM

Example: Even bits on I, odd bits on Q

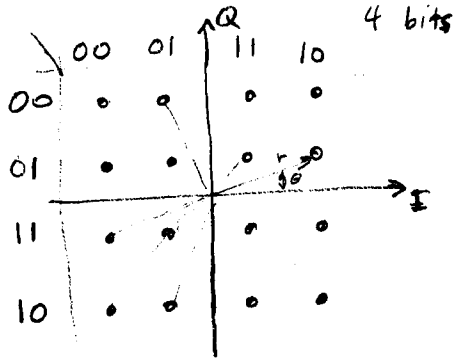


Too hard to draw --

data	phase
00	-135°
01	-45°
10	$+135^\circ$
11	$+45^\circ$

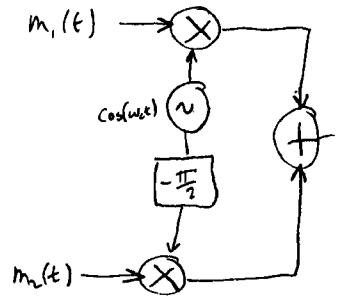
Using multiple levels -- "APK" = amplitude-phase keying

4 bits = 16 levels (4 each)

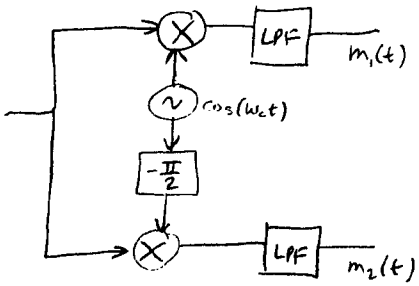


data	I	Q	Ampl	phase
0000	-1	+1	1.4	$+135^\circ$
0001	-.3	+1	1.1	$+107^\circ$
⋮				
0111	+.3	+.3	.09	$+45^\circ$
1111	+.3	-.3	.09	-45°
1110	+1	-.3	1.1	-17°

modulator



demodulator



APK: