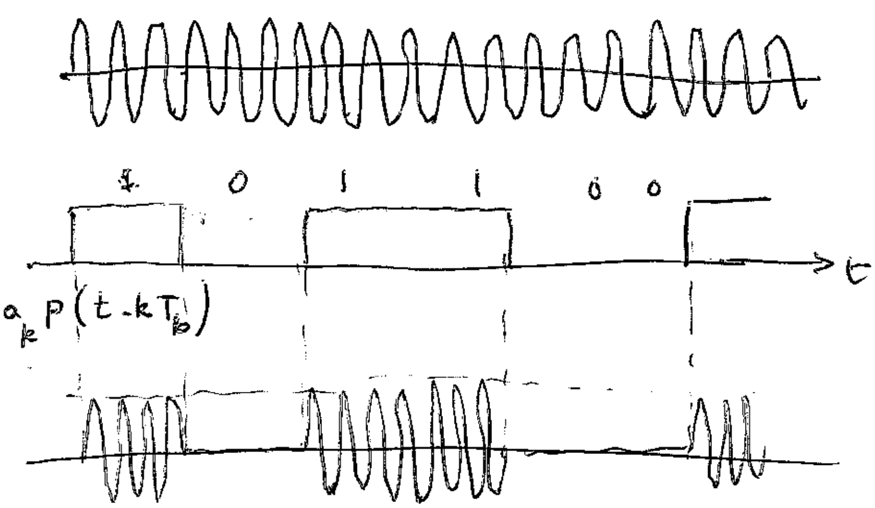
Lecture 16

Digital carrier systems:

This far, we have been talking about baseband signals. While these are suitable for transmission over wires or cables, they are not suitable for radio links. Why? Since we would require huge antennas to radiate LF spectrum. Hence, we need modulation. (Also for multiplexing, e.g. FDM)

(I) ON-OFF Keying (OOK) (aka Amplitude shift keying (ASK))



unmodulated carrier $\cos(2\pi f_c t)$

Baseband signal $m(t)$

$m(t) = \sum_k a_k p(t - kT_b)$

$a_k \in \{0, 1\}$

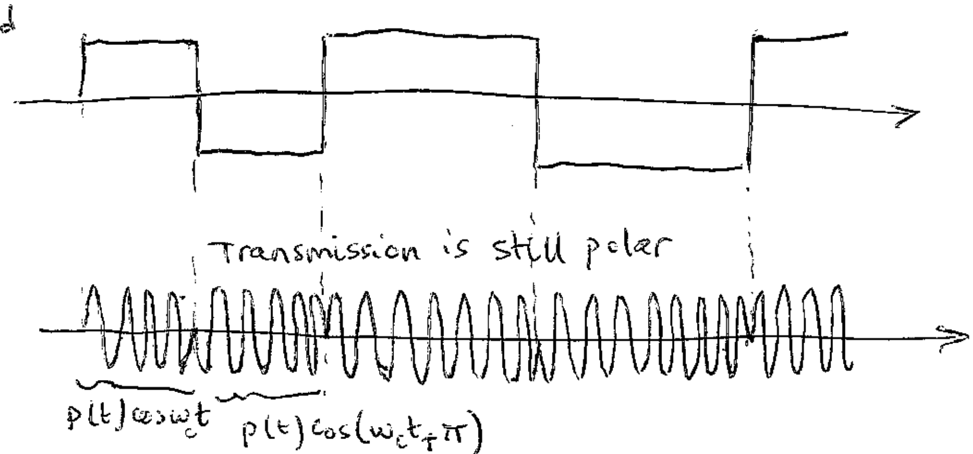
Modulated signal

$\phi_{ASK}(t) = m(t)\cos(\omega_c t)$

$= \sum_k a_k p(t - kT_b) \cos \omega_c t$

(II) Phase Shift Keying (PSK)

Baseband uses polar coding



$m(t) = \sum a_k p(t - kT)$

$a_k \in \{1, -1\}$

$1 \rightarrow p(t) \cos \omega_c t$

$0 \rightarrow -p(t) \cos \omega_c t$

$m(t) \cos \omega_c t = \phi_{PSK}(t)$

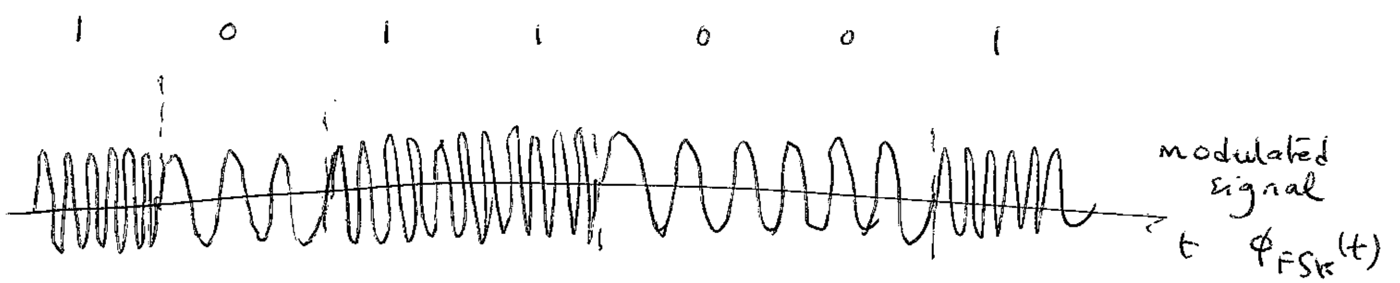
Two pulses are π radians apart in phase $\Rightarrow$ Information resides in the phase

III Frequency Shift Keying (FSK)

$0 \rightarrow \cos \omega_{c_0} t$

$1 \rightarrow \cos \omega_{c_1} t$

Information resides in the frequency



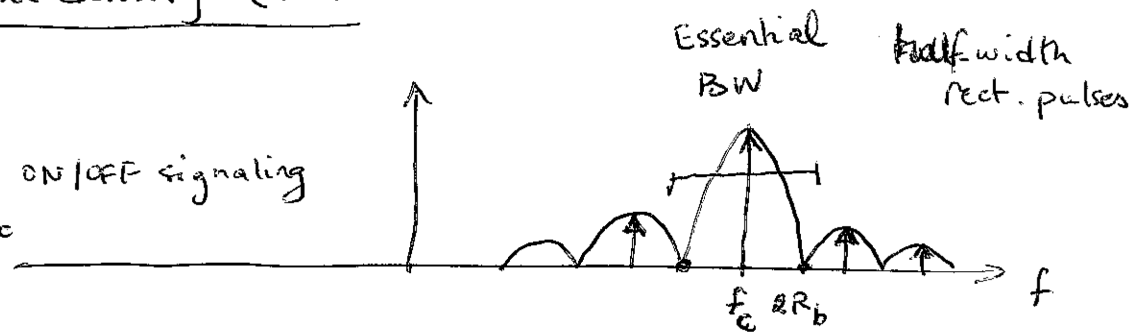
$$\phi_{FSK}(t) = \sum_k a_k\, p(t - kT_b) \cos(\omega_{c_1} t) + \sum_k (1 - a_k)\, p(t - kT_b) \cos(\omega_{c_0} t)$$

$a_k \in \{0, 1\}$

Power spectral density (PSD

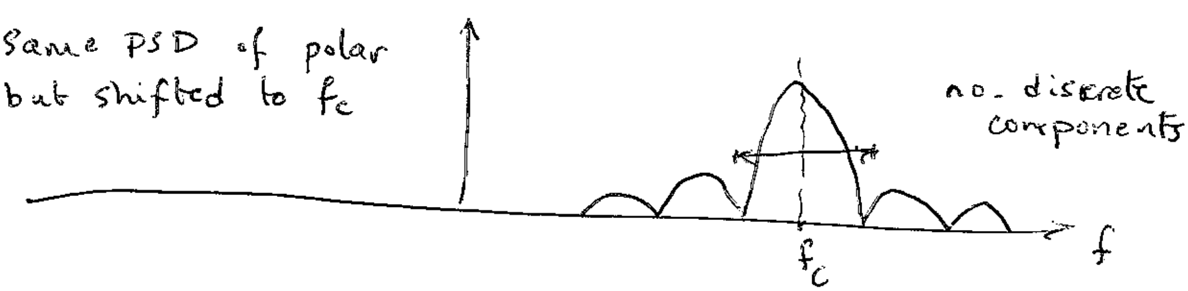
ASK

Same PSD of ON/OFF signaling but shifted to f_c



PSK

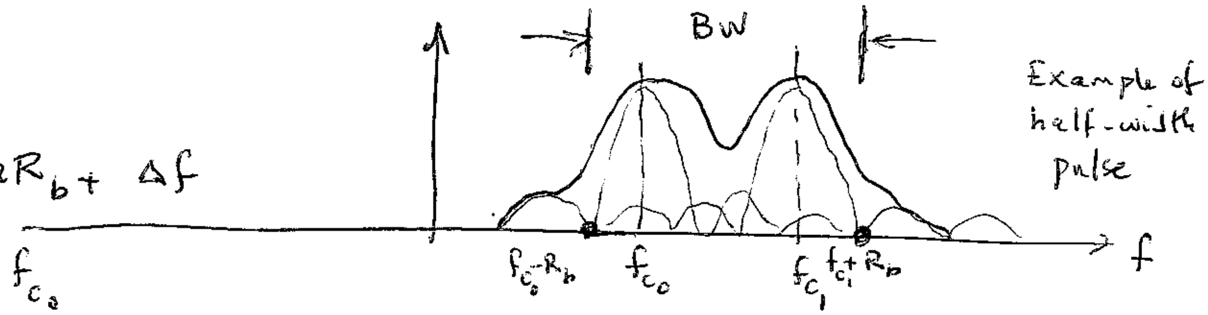
Same PSD of polar but shifted to f_c



FSK

$BW \simeq 2R_b + \Delta f$

$\Delta f = f_{c_1} - f_{c_0}$



Remark: 1) FSK can be viewed as the sum of 2 ASK signals (f_{c_0}, f_{c_1})

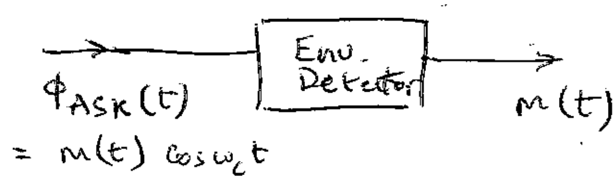
BW of FSK $>$ BW of PSK, ASK

2) We could also modulate any of the bipolar, duobinary, raised cosine, ... pulses

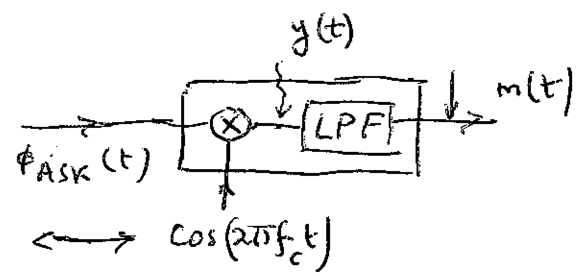
3) PSK requires 3 dB less power than ASK (or FSK) for same noise immunity (c.f. polar vs ON/OFF)

Demodulation: Can be coherent or incoherent (e.g. Envelope detector) simple but less accurate

ASK $\rightarrow$ can use coherent or incoherent



Incoherent detector



Coherent detector

$$\phi_{ASK}(t) = m(t)\cos(\omega_c t)$$

$$y(t) = \phi_{ASK}(t)\cos\omega_c t$$

$$= m(t)\cos^2(\omega_c t) = \frac{m(t)}{2}\left(1 + \cos 2\omega_c t\right)$$

PSK $\rightarrow$ coherent (cannot use the envelope detector)

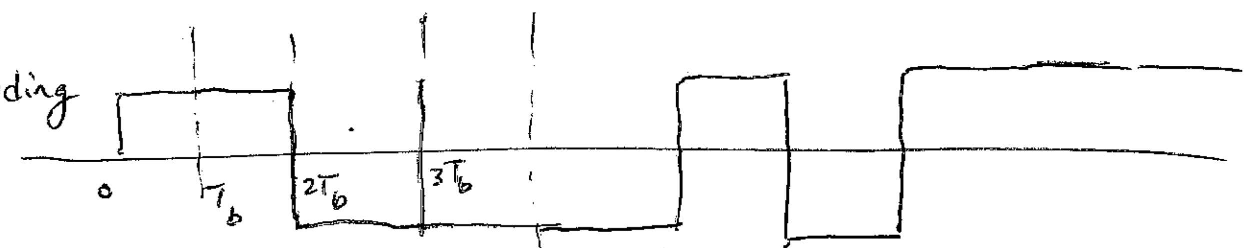
However, we can use DPSK (Differential PSK), which can be decoded incoherently. In particular, the data is encoded before modulation by a differential code, i.e.,

1 is encoded using the same pulse used to encode the previous pulse

and 0 " " " " negative " " " " " " "

Example: 1 1 0 1 1 0 0 0 1 1

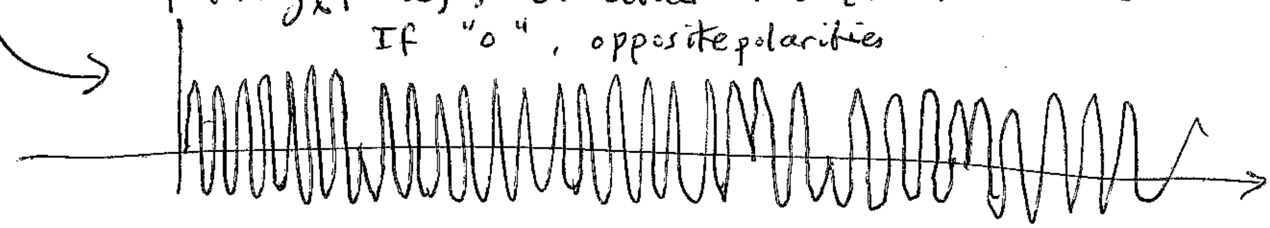
pre-coding



DPSK

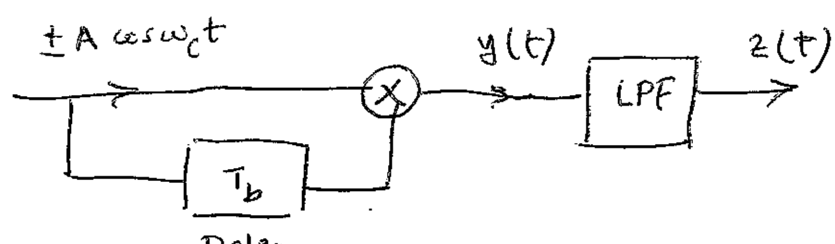
If "1", the present and previous pulses are of same polarity (phase), i.e. either $A\cos\omega_c t$ or $-A\cos\omega_c t$

If "0", opposite polarities



Demodulation of DPSK (Incoherent)

If two phase (consecutive) are identical



$\Rightarrow y(t) = A^2\cos^2\omega_c t$

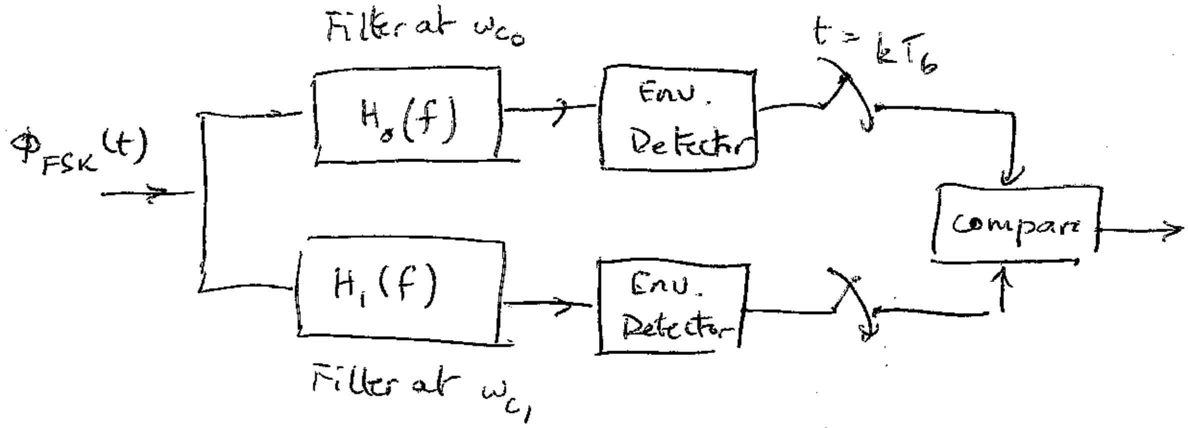
$= \frac{A^2}{2}(1+\cos 2\omega_c t) \Rightarrow z(t) = \frac{A^2}{2} \Rightarrow$ decode "1"

If opposite

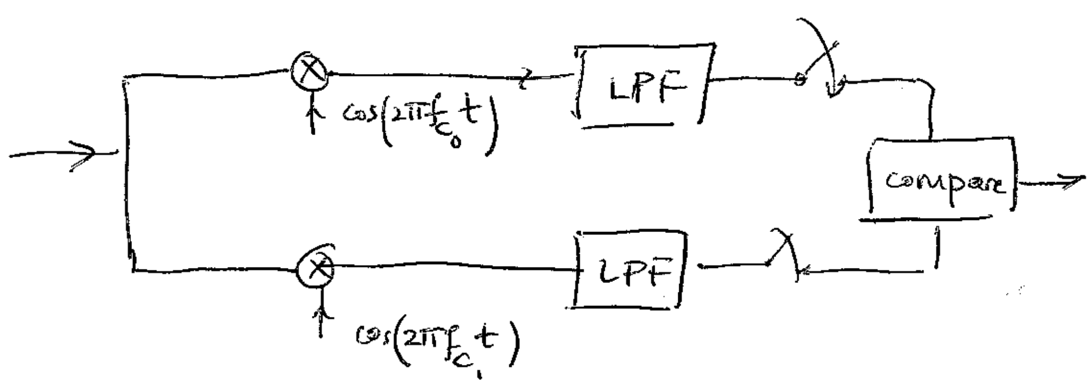
$\Rightarrow y(t) = -A^2\cos^2\omega_c t \Rightarrow z(t) = -\frac{A^2}{2} \Rightarrow$ decode "0"

FSK

FSK is two interleaved ASK $\Rightarrow$ coherent or incoherent demodulation



Incoherent demodulator of FSK



coherent detector of FSK

Coherent PSK has more noise immunity (superior to all other schemes) and also it requires smaller BW than FSK