Digital Modulation

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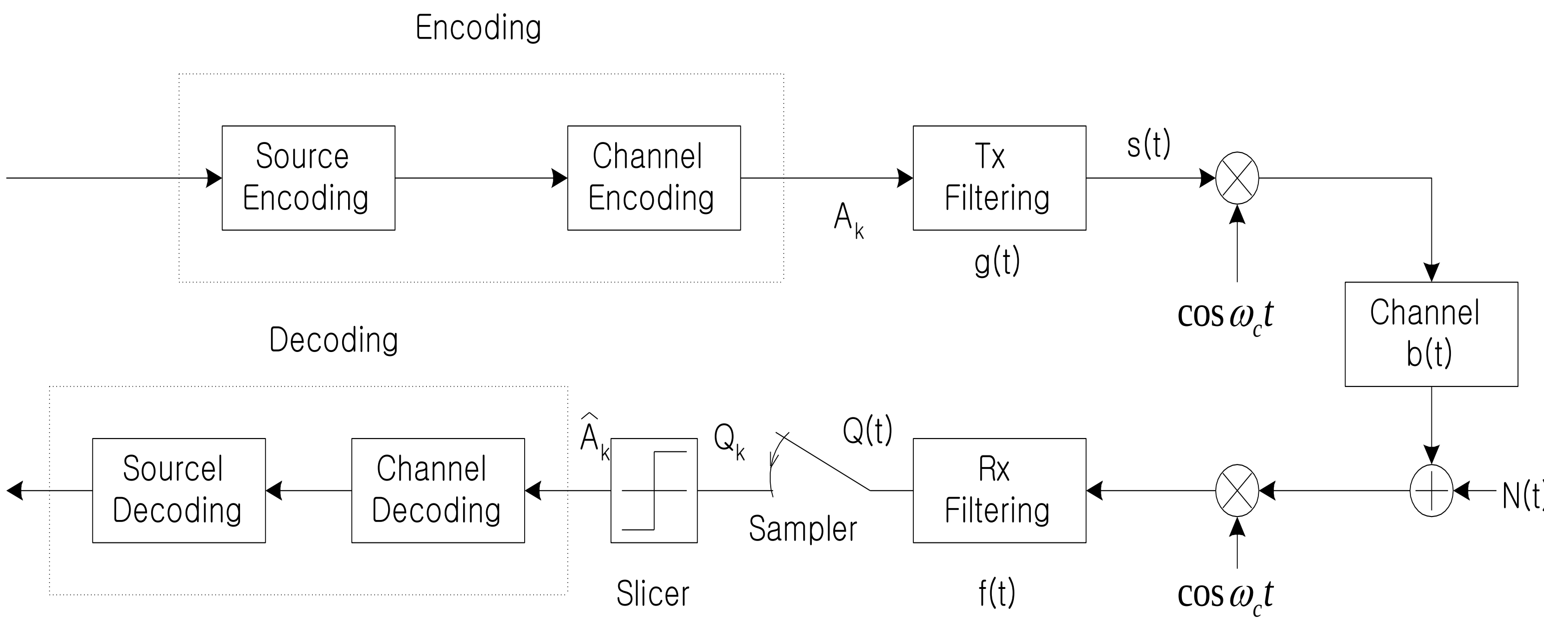
Why digital ?

- Noise robust
- Error correction
- Easy integration of various services
- Low cost
- Easy manufacturing

Comparison of modulation schemes

- Power efficiency
- Bandwidth efficiency
- Implementation complexity

Comm. system block diagram



$$s(t) = \sum_m A_m g(t - mT)$$

$$Q(t) = \sum_m A_m p(t - mT) + z(t)$$

$$z(t) = N(t) * f(t)$$

$$p(t) = g(t) * b(t) * f(t)$$

$$Q_k = Q(kT) = \sum_m A_m p(kT - mT) + z(kT)$$

$$= A_k p(0) + \sum_{m \neq k} A_m p(kT - mT) + z(kT)$$

$(If \;\; p(t) = 0 \; at \; non-zero \; multiples \; of \; T,$

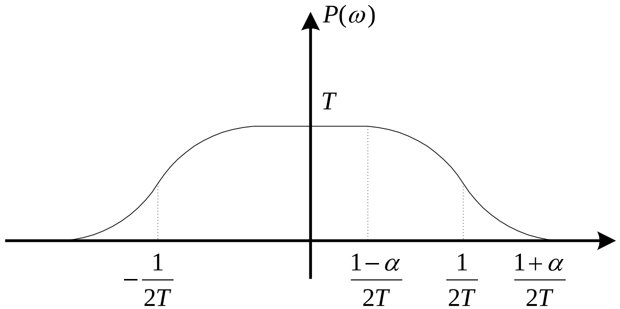
$then \;\; there \;\; is \;\; no \;\; ISI \,)$

- # Nyquist Criterion

$$p(t)\sum_{k=-\infty}^{\infty}\delta(t-kT) = \delta(t)$$

$$\frac{1}{T}\sum_{m=-\infty}^{\infty}P(j\omega - jm\frac{2\pi}{T}) = 1$$

  - Raised cosine filter



$$P(\omega)=\begin{cases} T & 0\le|\omega|<(1-\alpha)\frac{\pi}{T} \\ \frac{T}{2}\left[1-\sin\left(\frac{T}{2\alpha}\left(|\omega|-\frac{\pi}{T}\right)\right)\right] & (1-\alpha)\frac{\pi}{T}\le|\omega|<(1+\alpha)\frac{\pi}{T} \\ 0 & |\omega|\ge(1+\alpha)\frac{\pi}{T} \end{cases}$$

  - Tx,Rx filter SRC (Square-Root Raised Cosine) filter

Modulation types

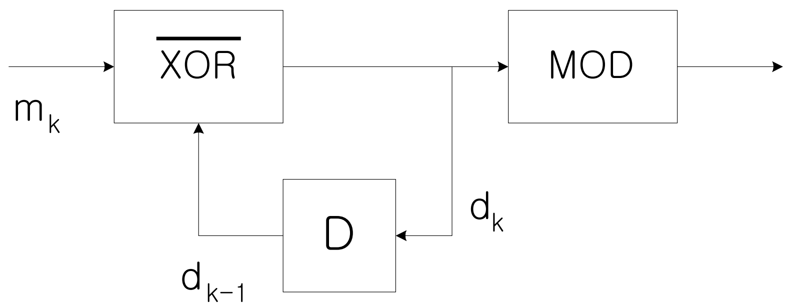
- BPSK

$$P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

- QPSK

$$P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

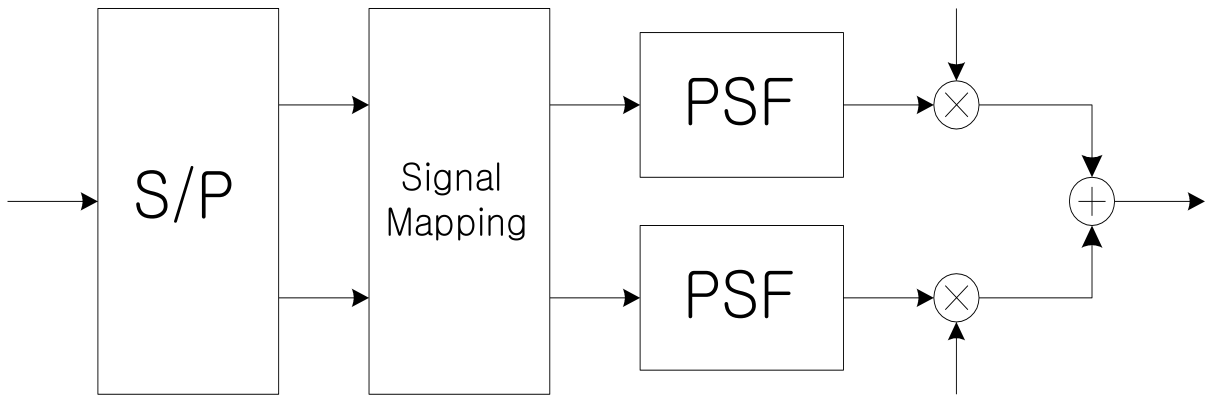
• DPSK(Differentially Encoded PSK)



M_k	:		1	0	0	1	0
d_{k-1}	:		1	1	0	1	1
d_k	:	1	1	0	1	1	0

$$P_{e,DPSK} = \frac{1}{2}\exp\left(-\frac{E_b}{N_O}\right)$$: Differential decoding

– Transmitter

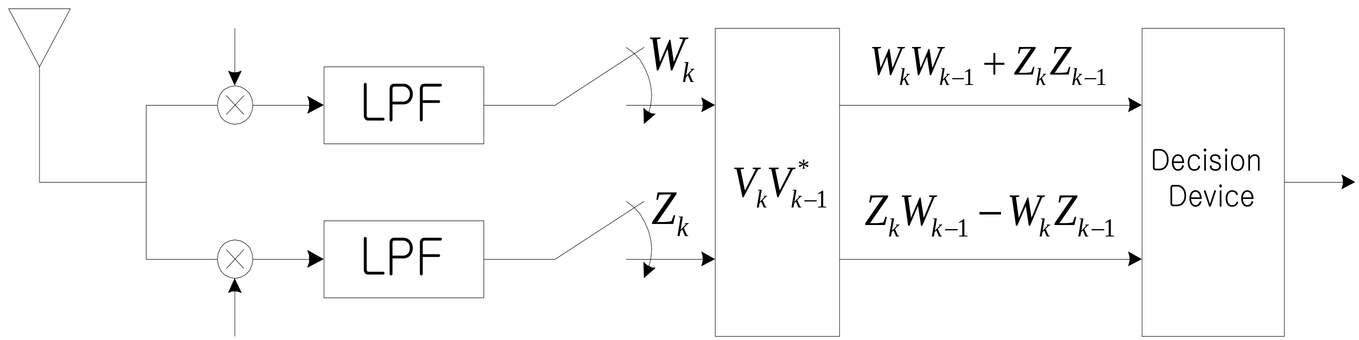


– Receiver

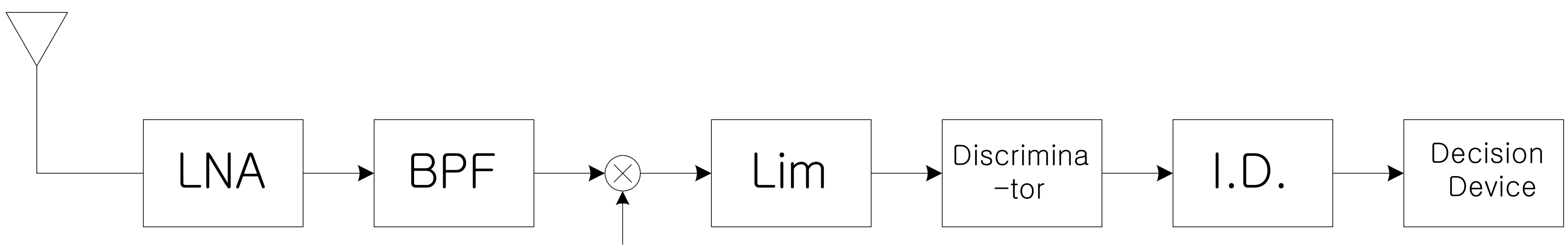
Received signal at t=*kT*: V_k

Phase change : $V_k V_{k-1}^*$

- Implementation 1



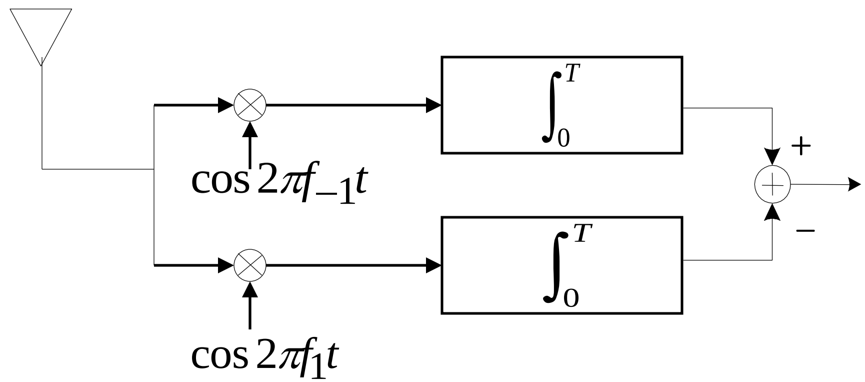
Implementation 2 (LDI Receiver)



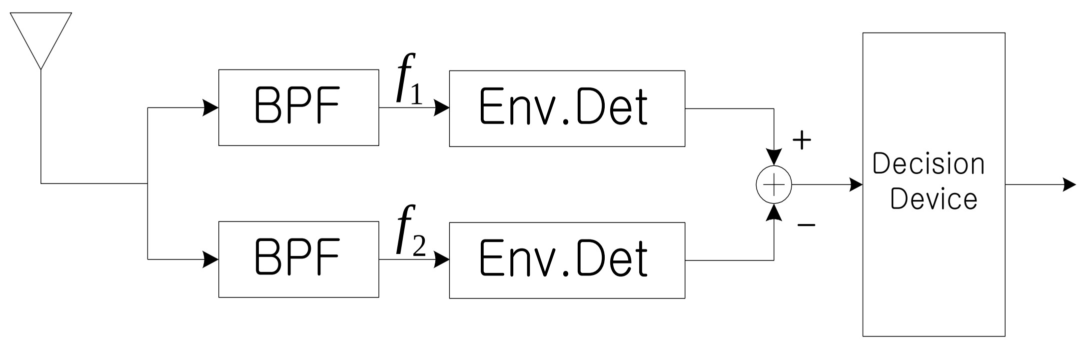
- Constant envelope modulation
  - FSK
  - MSK, GMSK
  - GFSK

  - Advantages
    - Power Amp. Efficiency
    - simple receiver implementations

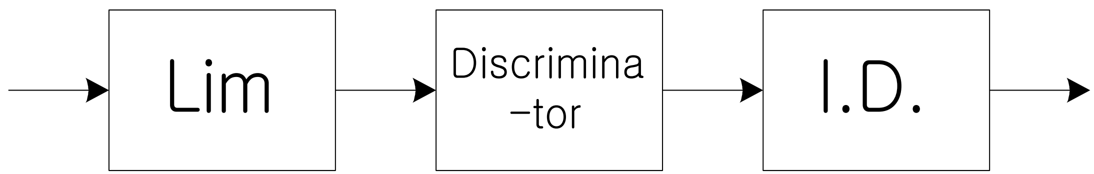
- FSK
  - Coherent demodulation



  - Noncoherent demodulation 1



– Noncoherent demodulation 2
(LDI detector)



• MSK

$s_{-1} = \cos\left(2\pi(f_c - \Delta f)t + \theta_1\right)$

$s_1 = \cos\left(2\pi(f_c + \Delta f)t + \theta_2\right)$

Δf : s_1, s_2 orthogonal → MSK

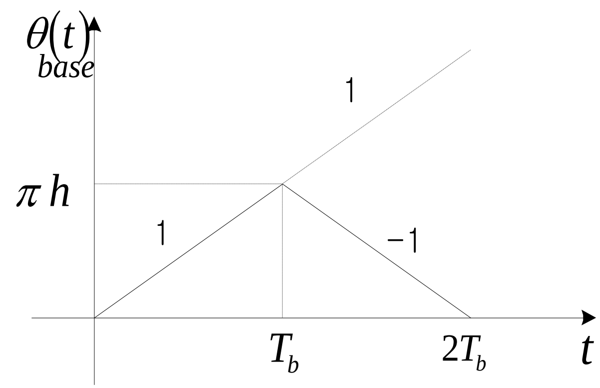
$$h = \frac{2(\Delta f)}{R_b}$$

If $h = \frac{1}{2}$, then s_1, s_2 are orthogonal.

$$\rightarrow 2\Delta f = \frac{R_b}{2} = \frac{1}{2T_b}$$

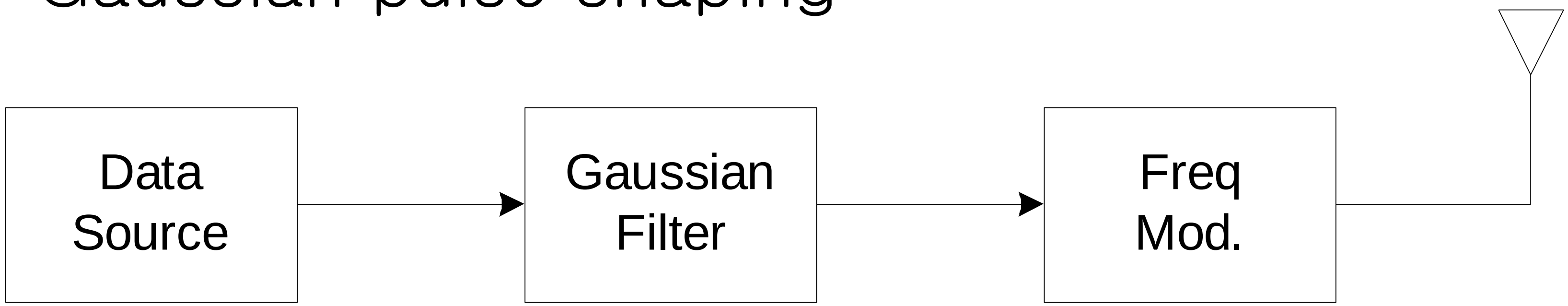
$$\theta(\mathrm{t}) = 2\pi(f_c + \Delta f)t$$

$$\theta_{base}(\mathrm{t}) = 2\pi\Delta f t = 2\Delta f \pi t = \frac{h}{T_b}\pi t$$



- GMSK

  Gaussian pulse shaping



  Effects of Gaussian filter BW: Spectrum, ISI

- GFSK
- Bluetooth: GFSK & PSK

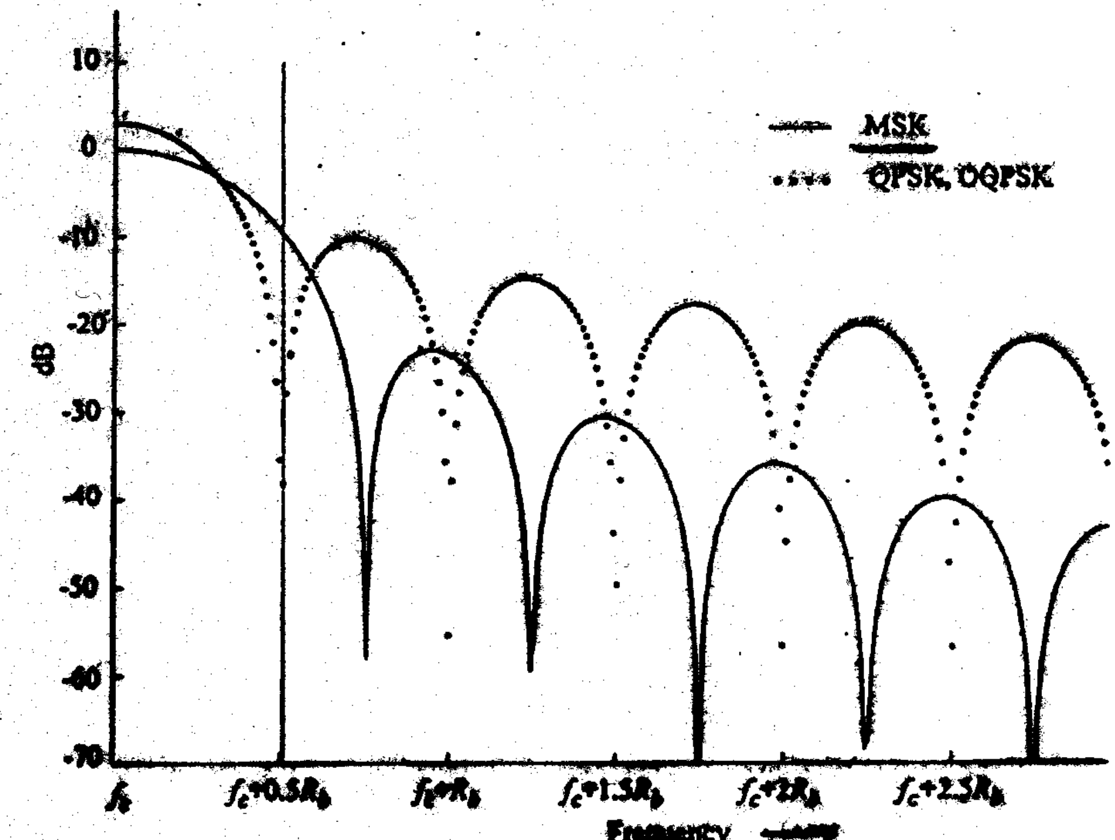


Figure 5.38
Power spectral density of MSK signals as compared to QPSK and OQPSK signals.

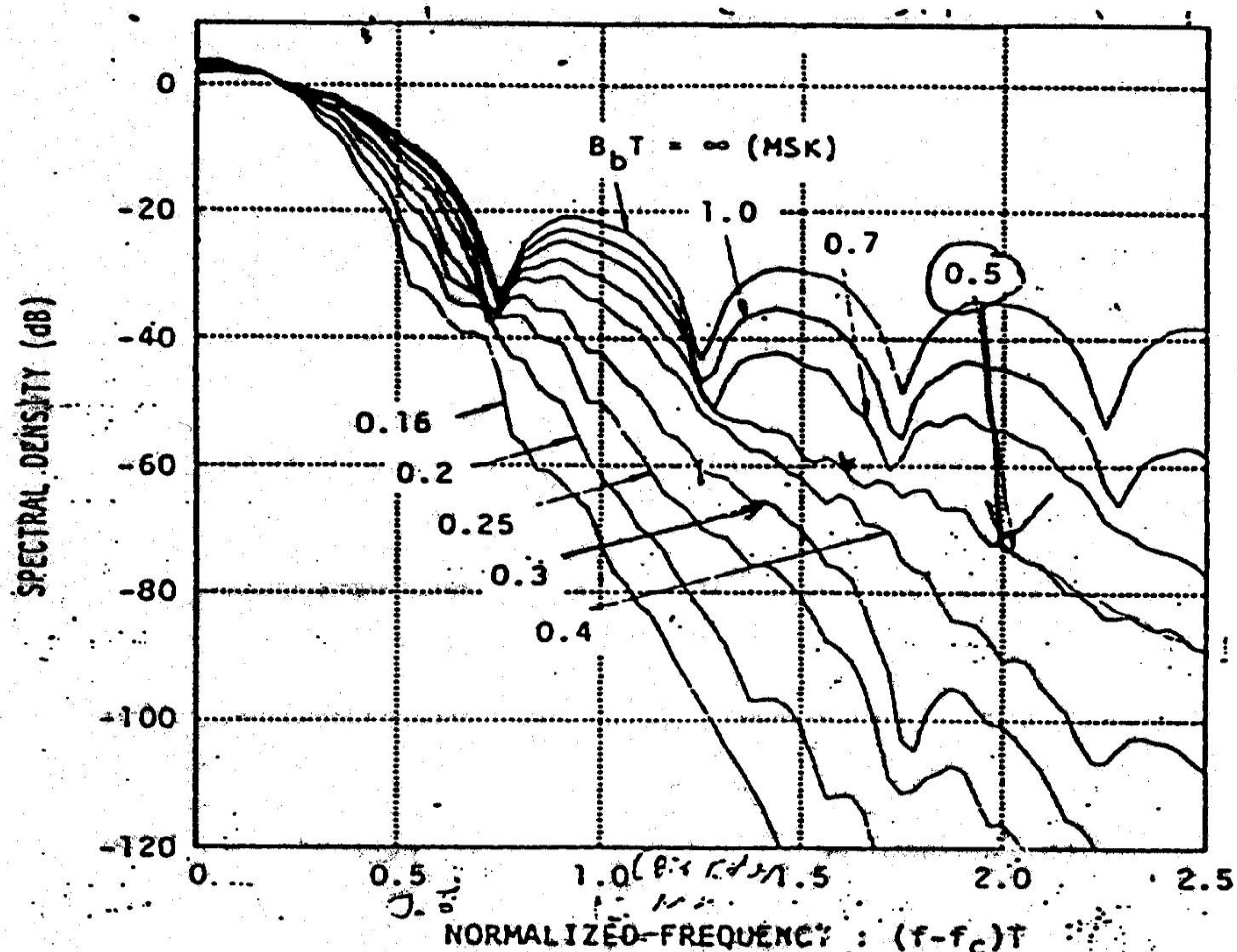


Fig. 2. Power spectra of GMSK.

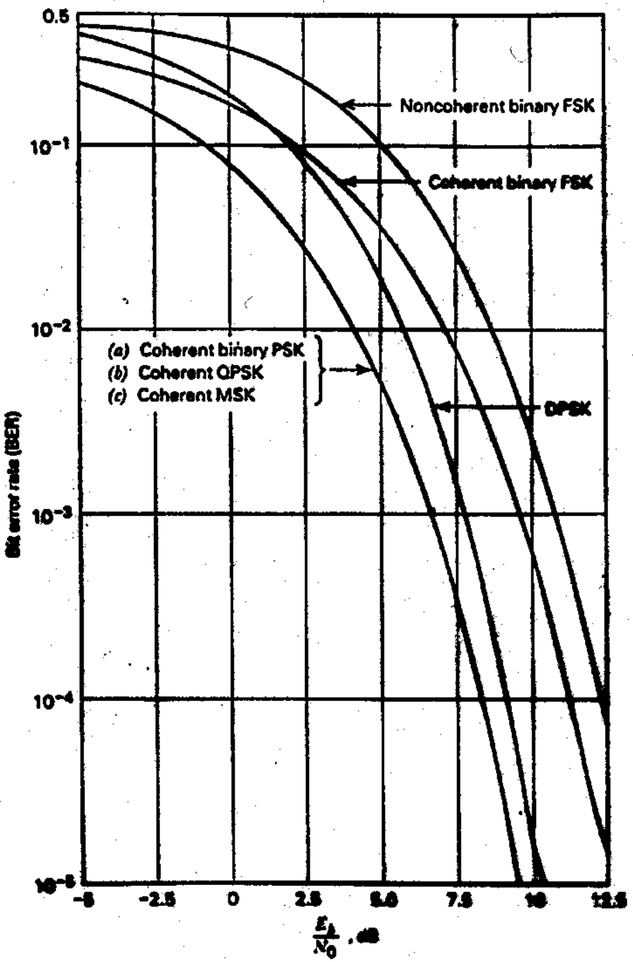
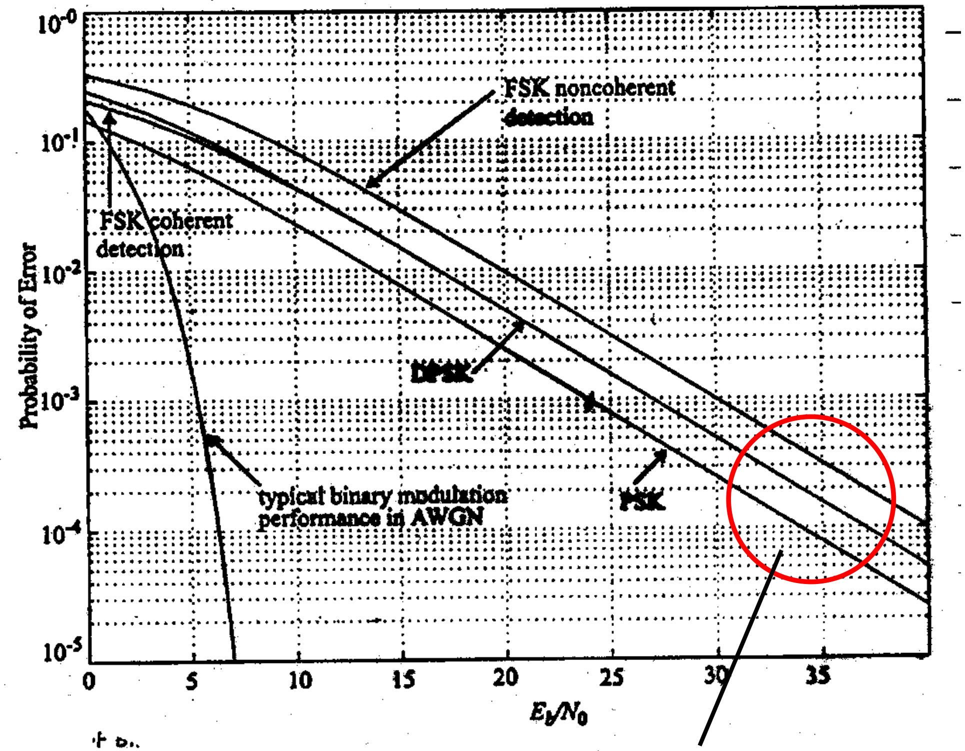


Figure 8.32 Comparison of the noise performances of different PSK and FSK schemes.



Fading channel performance