Introduction to Spread Spectrum

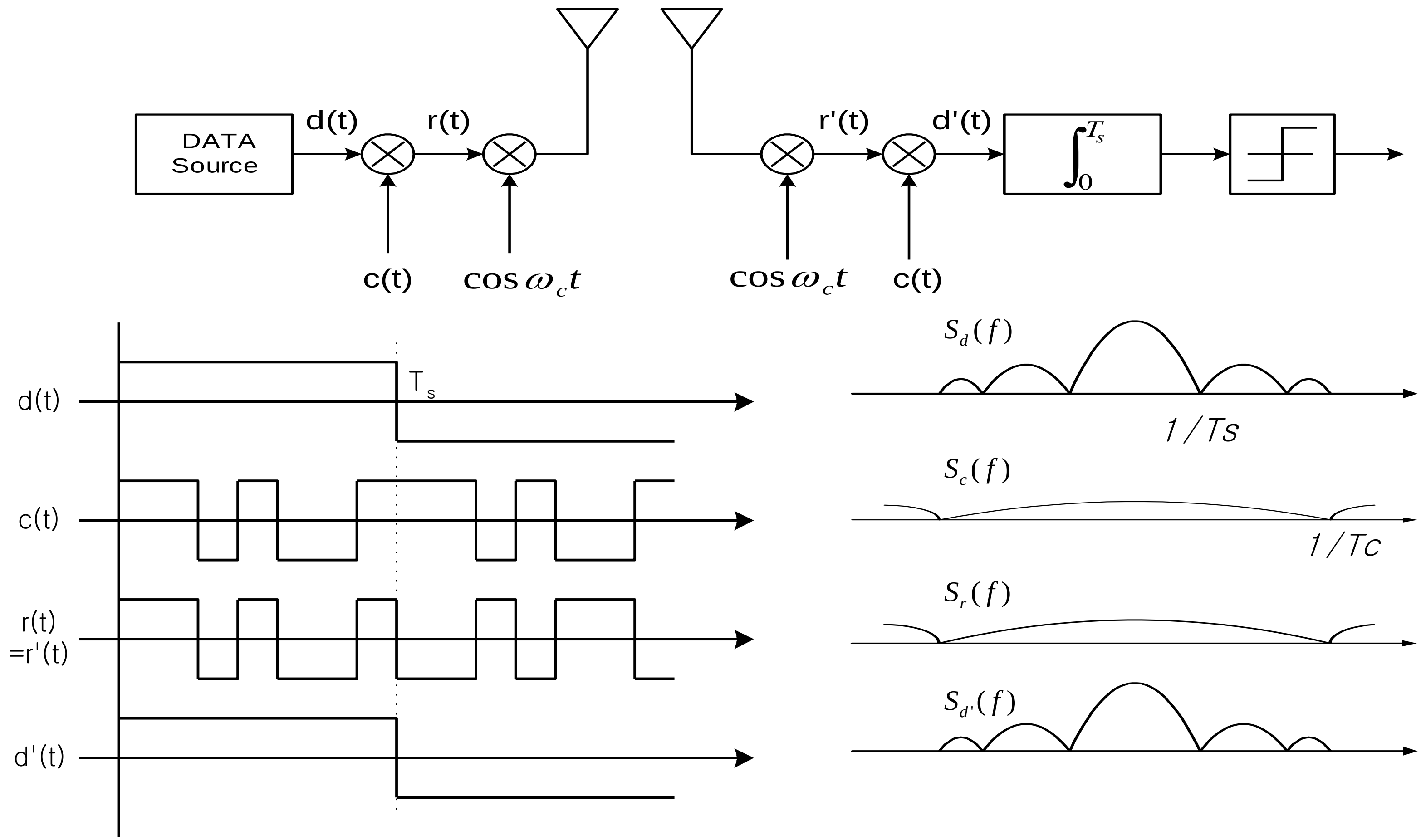
Contents

- Introduction
- DS/SS
- Frequency hopping

Introduction

- Initial application: military
- Benefits
  - Anti-jamming
  - Robust to multipath fading
  - Multiple User Access (CDMA)
  - High resolution ranging (DS)

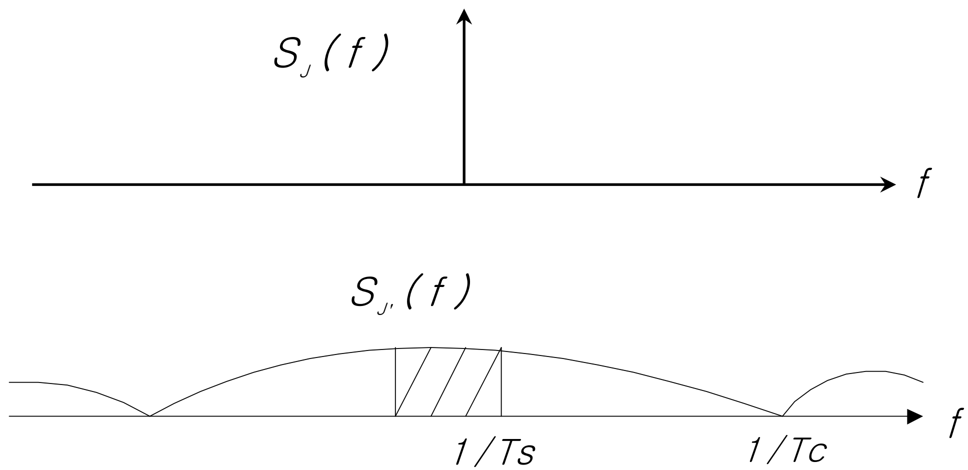
DS/SS



DATA
Source
d(t)
r(t)
c(t)
$\cos\omega_c t$
$\cos\omega_c t$
c(t)
r'(t)
d'(t)
$\int_0^{T_s}$
d(t)
T_s
c(t)
r(t)
=r'(t)
d'(t)
$S_d(f)$
1/Ts
$S_c(f)$
1/Tc
$S_r(f)$
$S_{d'}(f)$

Anti-Jamming effect

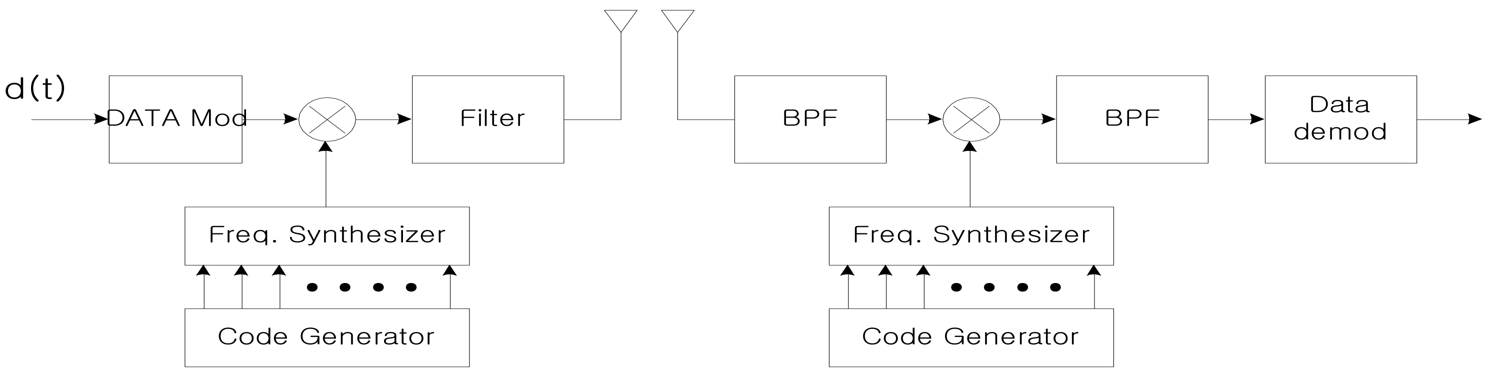
- Interfering Signal: tone



- Tone Jamming signal is spread out by despreading operation.
- Small part of a jamming signal goes through the rx filter.
- Jamming effect reduction factor : $\frac{Ts}{Tc}$

Frequency hopping

- The carrier frequency is pseudo randomly hopped over various frequencies.



Slow hopping : $T_{symbol} < T_{hopping}$

Fast hopping : $T_{symbol} > T_{hopping}$

* Noncoherent scheme is common.

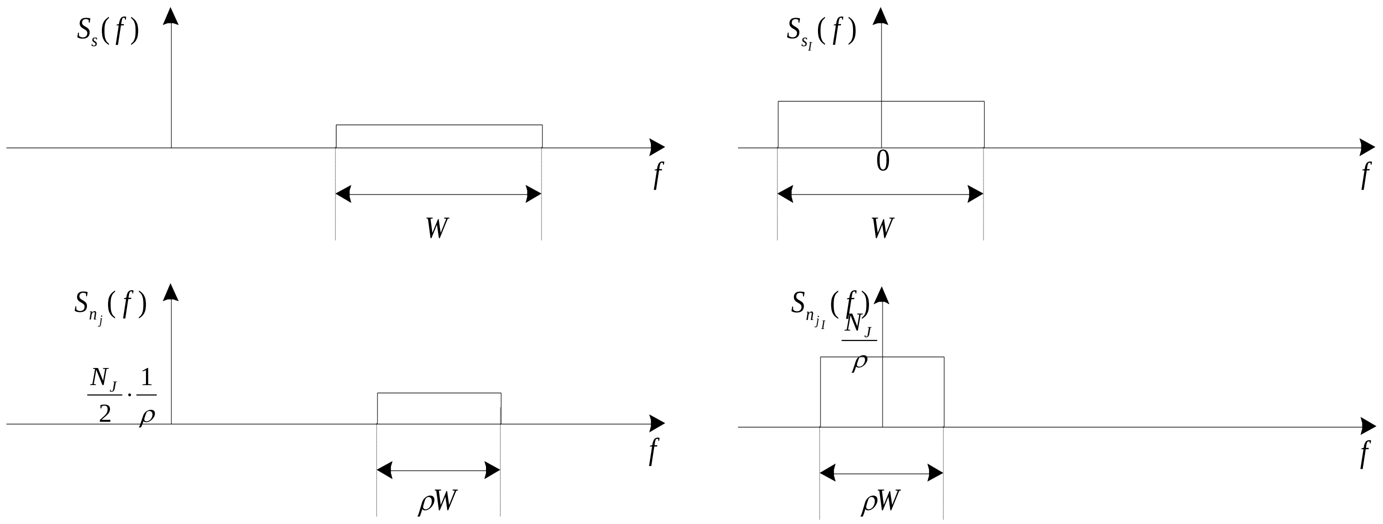
Performance of SS (Jamming)

Contents

- Performance in partial band jamming in DS/CDMA systems
- Pulse noise jammer in DS/CDMA systems
- Partial band jammer in FH systems
- Reference : "Introduction to spread spectrum communications." by peterson…

Performance in partial band jamming

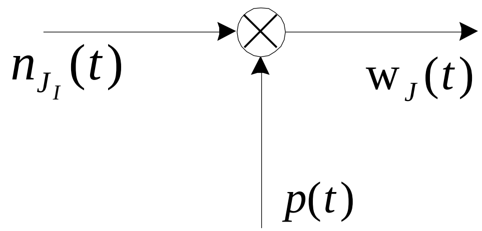
$$r(t) = s(t) + n(t) + n_j(t); \quad s(t)\text{의 } BW = W, \quad PBJ\text{의 } BW = \rho W$$



Total Jamming Power = J

$$\frac{N_J}{2} = \frac{J}{2W}$$

PBJ PSD= $\frac{N_J}{2}\cdot\frac{1}{\rho}$



$$W_J(t) = n_{J_I}(t) \cdot p(t)$$

$$\Rightarrow R_{W_J}(\tau) = R_{N_{J_I}}(\tau) \cdot R_p(\tau)$$

$$S_{W_J}(f) = S_{n_{J_I}}(f) \otimes S_p(f)$$

$$= \int_{-\infty}^{\infty} T_c \sin c^2(\tau T_c) S_{N_{J_I}}(f-\tau) d\tau$$

$$= \int_{f-\frac{\rho W}{2}}^{f+\frac{\rho W}{2}} T_c \sin c^2(\tau T_c) \frac{N_J}{\rho} d\tau$$

$$= \frac{N_J}{\rho} T_c \int_{f-\frac{\rho W}{2}}^{f+\frac{\rho W}{2}} \sin c^2(\tau T_c) d\tau$$

Case 1 :

$$\rho = 1$$

$$S_{W_J}(0) = N_J T_c \int_{-\frac{W}{2}}^{\frac{W}{2}} \sin c^2(\tau T_c) d\tau$$

$$If \;\; \frac{W}{2} = \frac{1}{T_c}, \qquad S_{W_J}(0) = 0.9\, N_J$$

Case 2 :

$$\text{small}\, \rho,\;\; \rho W << \frac{1}{T_c} \Rightarrow \sin c^2(\tau T_c) \cong 1$$

$$S_{W_J}(0) = \frac{N_J}{\rho} T_c \rho W = N_J T_c \mathrm{W}$$

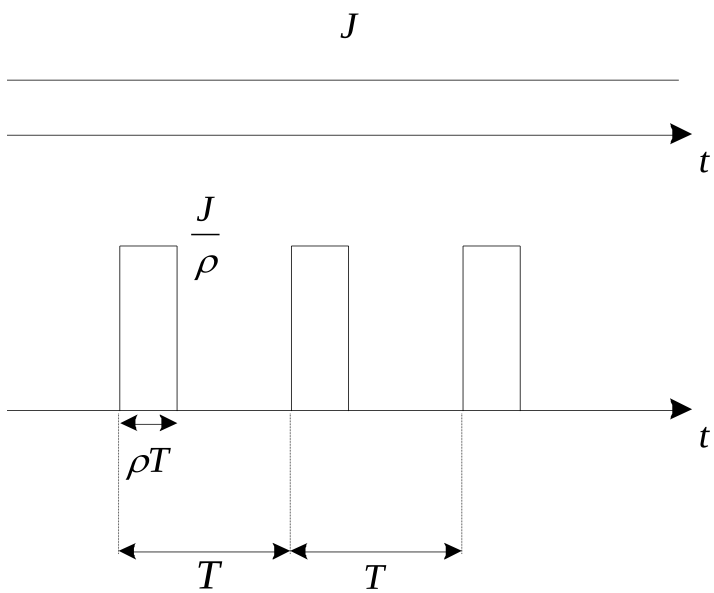
$$= \frac{J}{\mathrm{W}} T_c \cdot W = J T_c$$

$$If \;\; \frac{W}{2} = \frac{1}{T_c},$$

$$S_{W_J}(0) = J T_c = \frac{J}{\frac{1}{T_c}} = \frac{J}{\frac{W}{2}} = 2 N_J$$

Pulse noise jammer

- Jamming power J is fixed



- Prob. of Error = $\rho f\left(\dfrac{E_b}{N_0 + N_J/\rho}\right) + (1-\rho) f\left(\dfrac{E_b}{N_0}\right)$

$$f\left(\frac{E_b}{N_0}\right) : \text{BER equation}$$

- Assume $f\left(\dfrac{E_b}{N_0}\right) \cong 0,$

$$N_J = J/W \quad E_b = P/R$$

$$P_e \approx \rho f\left(\frac{\rho E_b}{N_J}\right) = \rho f\left(\rho \frac{P}{R} \cdot \frac{W}{J}\right)$$

$$= \rho f\left(\rho \frac{P}{J} \cdot \frac{W}{R}\right)$$

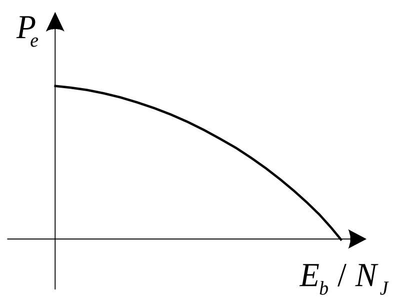
- For BPSK, $P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$

  In pulse noise jamming

$$P_e \approx \rho\, Q\left(\sqrt{\rho \frac{2E_b}{N_J}}\right) = \rho\, Q\left(\sqrt{2\rho \frac{P}{R}\cdot\frac{W}{J}}\right)$$

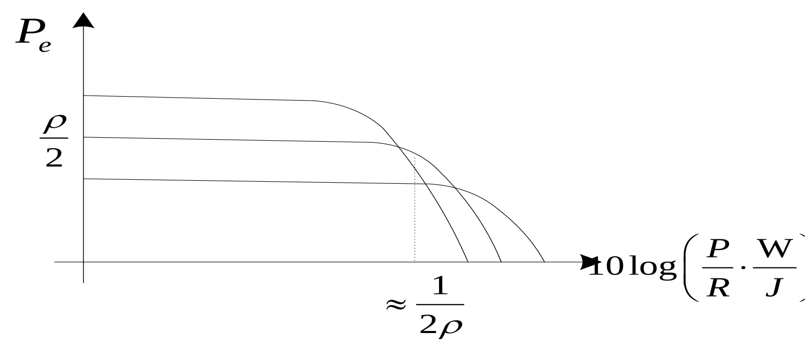
Case 1: $\rho = 1$

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



Case 2: $\rho \frac{2E_b}{N_J}$ is small

$$P_e = \frac{\rho}{2}$$

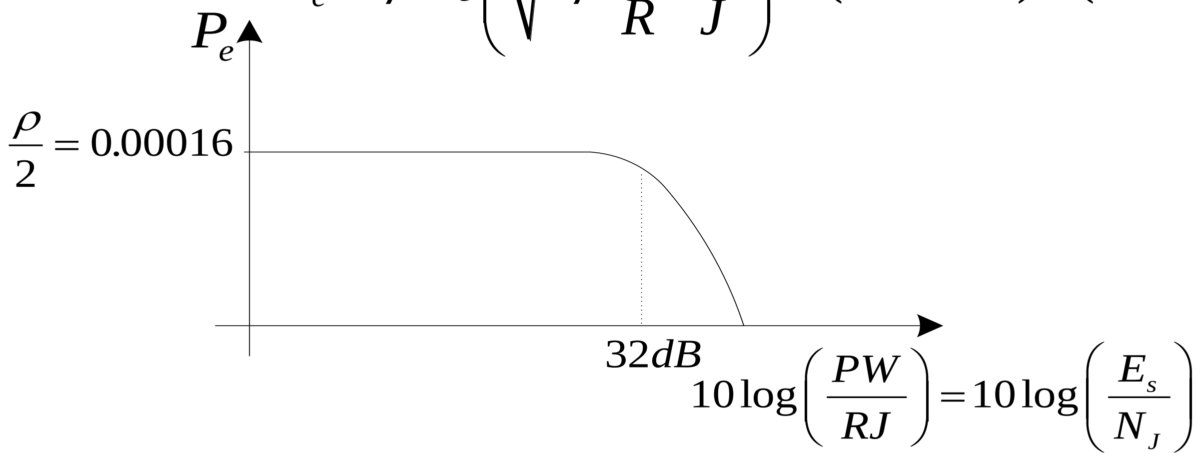


- example

$$\rho = 0.00032$$

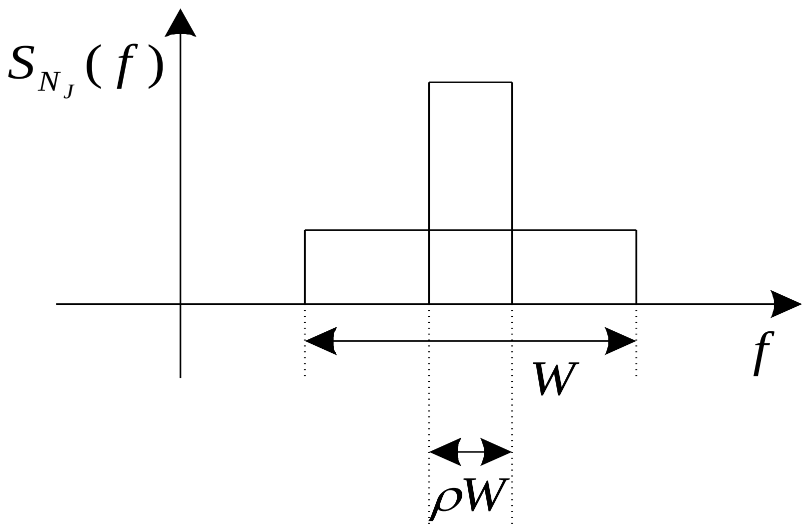
$$2\rho \frac{PW}{RJ} = 1 \rightarrow \frac{PW}{RJ} = \frac{1}{2\rho} = 1562.5 \Rightarrow 10\log(1562.5) = 32dB$$

$$P_e = \rho\, Q\left(\sqrt{2\rho \frac{P}{R} \cdot \frac{W}{J}}\right) = (0.00032) \times (0.1587)$$



- Optimal ρ
- Pulse noise jammer in DS-CDMA systems and systems without spreading

Partial band jammer in FH system

- 

- $$P_e = \rho f\left(\frac{E_b}{N_0 + \frac{N_J}{\rho}}\right) + (1-\rho)\, f\left(\frac{E_b}{N_0}\right) \approx \rho f\left(\frac{\rho E_b}{N_J}\right)$$