Variables

E_b - Energy / bit
$I_{total} = I_t$ - Interference Total
I_{oc} - Interference other cell
I_o - Own cell interference
m - # of users in cell
S - Signal Power of each user at B.S.
V_f - average reverse link activity factor (voice factor)

$$f = \frac{\text{Total other cell received power}}{\text{Total own-cell received power}} = \text{frequency reuse factor}$$

$$\eta = \frac{1}{1+f} \quad \text{re-use efficiency}$$

γ - path loss exponent
σ - standard deviation of path loss

$$\rho = \frac{m}{m_{max}} \approx \frac{I_t}{I_t + N_t} = \text{Cell Loading with reference to thermal noise.}$$

$$N_t = F k_B T B_w = \text{thermal Noise}$$

R_c - Chip Rate
R - data Rate

$$G_p = \frac{R_c}{R} - \text{Processing Gain}$$

$B_w = R_c$ Spreading Bandwidth
N_o = power spectral density $= F k_B T$
η_c = power control factor

Signal Strength S in dB

$$S = P_m + \underbrace{G_m + G_b + G_{dv} + G_{sho}}_{\text{Gains}} + \underbrace{L_p \; M_{fade} + L_{body} + L_{pent} + L_{cable}}_{\text{Losses}}$$

P_m - transmit Power
G_m - Mobile Antenna Gain
G_b - Base Station Antenna Gain
G_{dv} - Base Station Antenna Diversity
G_{sho} - Soft handoff Gain
L_p - path loss $= L_0 + 10\,\gamma \log r$
M_{fade} - fading margin
L_{body} - body loss
L_{pent} - penetration loss
L_{cable} - cable loss

(L_0 ← path loss intercept, ie. path loss in dB at 1km)

CDMA Link Budget

Concepts

Interference Limited System

Hand-off

  Soft hand off - Use multiple base stations

Quality of Service

  Mean Opinion Score (MOS)

  Frame Error Rate (FER)

  E_b/I_t

  Call drop Rate

Forward Direction Base → Mobile

Reverse Direction Mobile → Base

Pilot Signal → Forward Direction, Coherent Reference

Capacity - Usually Reverse Link limited

Pole Point, Asymptotic Cell Capacity - Ignore $F k_0 T B$ noise

$\frac{E_b}{I_t} > 5-7$ dB for satisfactory performance $\approx 3-5$

Power Control

Cell Loading - Figure 10.1

Noise Rise $\eta = \frac{P_{total}}{N_T} = \frac{1}{1-\rho}$

Equations

$$I_{total} = I_o + I_{oc} \qquad 10.3$$

$$I_o = (m-1) \cdot S \cdot v_f \qquad 10.1$$

$$I_{oc} = f \cdot m \cdot S \cdot v_f \qquad E_b = \frac{S}{R}$$

Reverse Link Capacity

In absence of thermal noise

$$\frac{E_b}{I_t} = \frac{v_f\, S\, G_p}{I_o + I_{oc}} = \frac{v_f\, S\, G_p}{(m-1) \cdot S \cdot v_f + f \cdot m \cdot S \cdot v_f} \qquad 10.7$$

Single Cell System without thermal Noise

$$\frac{E_b}{I_t} = \frac{G_p}{(m-1)} \qquad 10.7$$

With thermal noise included & power control

$$\frac{E_b}{I_t} = G_p \frac{S\, n_c}{\text{thermal} + I_o + I_{oc}}$$

Power Control

$$\frac{E_b}{I_t} = G_p \frac{S\, n_c}{F k_B T B_w + (m-1) \cdot S \cdot v_f + f \cdot m \cdot S \cdot v_f}$$

Link Budget CDMA

Energy per bit to Interference Ratio

$\frac{E_b}{I_t}$ (dB) $\frac{E_c}{I_t}$ is used for pilot Channel since it carries no data, only code

can be calculated many ways 10.9, 10.13,

Energy per bit

$E_b = \frac{S}{R} = \frac{\text{Signal strength}}{\text{data rate}}$ ← This is linear, not dB

$= 10 \log_{10} S - 10 \log_{10} R$ ← This is dB

Signal Strength comes from "Link Budget" we learned before (See 10.14, 10.51, 10.55

$S = P_{received} = P_{transmitted} + \text{Gains} - \text{Losses}$ (dB)

$= (P_{trans})(\text{Gains})(\text{Losses})$ (Linear)

Interference comes from

Self Cell $I_o = (M-1) S v_f / B_W$ (10.10)

Other Cell $I_{oc} = f\ M\ S\ v_f / B_W$ (10.2) Often neglected

Noise $N_o B_W = F T k_b B_W$

↑ Noise figure

Total interference

$I_t = I_o + I_{oc} + N_o B_W$

Figure of Merit
The data link will "work" when the Figure of Merit is positive. (when you receive enough power)

$$M_{FOM} = \left(\frac{E_b}{I_t}\right)_{\substack{\text{actually}\\ \text{received}}} - \left(\frac{E_b}{I_t}\right)_{\substack{\text{design}\\ \text{specified}\\ \text{(min)}}} > 0$$

Now, what can be calculated from this?

- Cell Radius – using Log Distance model

$$S_{max} = S_{1km} + 10\gamma \log r \qquad (10.30)$$

↑ path loss exponent

$$r = 10^{\frac{+S_{max} - S_{1km}}{10\gamma}} \quad \text{or} \quad 10^{\frac{-L_{max} + L_{1km}}{10\gamma}} \text{ (km)}$$

- Max # of users (Assuming Full channel use)

$$M_{max} \sim \frac{G_p \eta_c}{\left(\frac{E_b}{I_t}\right) \nu_f (1+f)} \qquad (10.22)$$

Imperfect Power Control

Also per sector per cell, etc.

- Realistic # of users

$$\frac{M}{M_{max}} = \rho \text{ cell loading factor} < 1 \qquad (10.26)$$

- Capacity (of a cell, sector, etc)

depends on call blocking – use Erlang B charts

other things that affect capacity
overhead of control channels (pilot, sync, page)
handoff
power control η