9. MOBILE COMMUNICATIONS

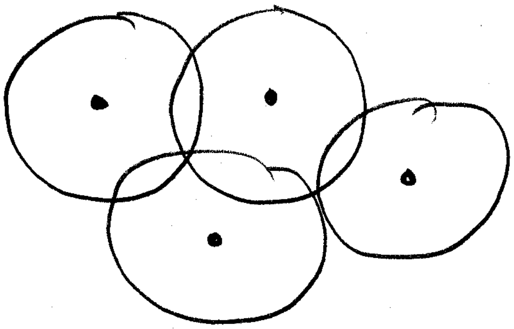
- Wireless communication — mobile radio, personal communications, etc — is evolving rapidly in both commercial applications and theory

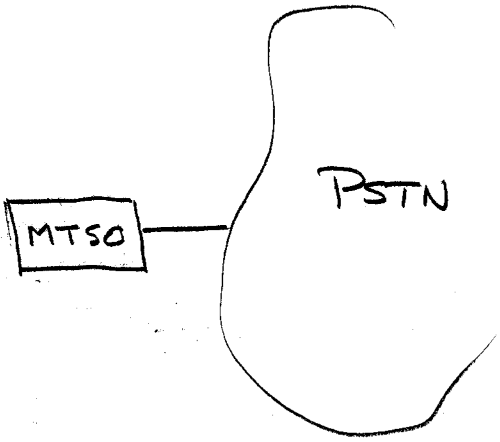
- This treatment will be only an introduction. A good presentation would easily fill two courses.

- We'll deal only with the dominant phenomena as they relate to the theme of this course
  - — propagation phenomena
  - — their effect on detection and performance
  - — specialized modulation formats

9.1 Propagation Phenomena

- Wide area radio systems are divided into cells, each with a base station that carries the antennas and is connected to the wireline network



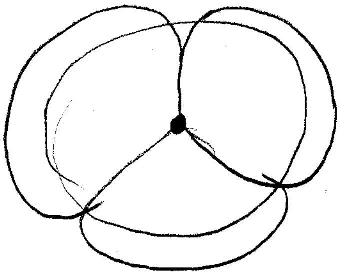


The rationale?

- compensate for propagation loss
- reduce the traffic handled by each base

- Minimize interference between signals in different cells:
  - reuse the same frequency only in distant cells
  - reuse the same time slot only in distant cells
  - use different spreading codes in each cell

- Minimize interference among signals in the same cell
  - sectorized antennas, typ. 120°



  - different frequencies, different time slots, different spreading codes
  - multiuser detection (still research)

- Before discussion of propagation, establish scales:

- carrier $f_c = 1$ GHz or so $\lambda = \frac{c}{f_c} = 30$ cm or so

  phase change of 2π in 1 ns or 30 cm.

- modulation
  - → If symbol rate is 20 kHz (low) then one symbol is $c/20$ kHz $= 15$ km long.
  - → If 200 kb/s, a bit is 1.5 km long.
  - → If spread bandwidth (e.g. CDMA) to 1.25 MHz

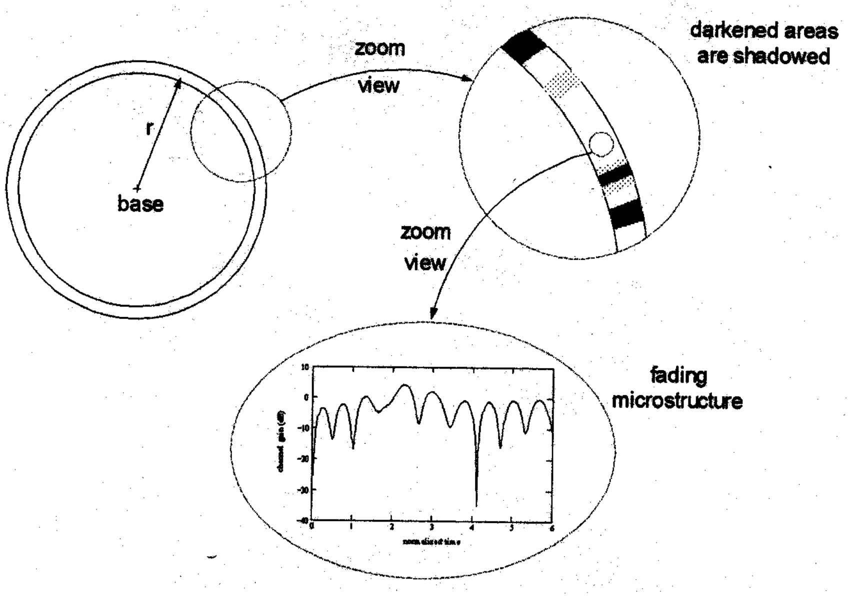
    [illegible]

    sym = 128 chips

    each chip is about 200 m long

- The main propagation phenomena in mobile communications are
  - path loss (the farther, the weaker)
  - shadowing (obstacles between base, mobile)
  - fading (interference among scattered components)

They are nested — increasingly local scale, each with mean square value determined by the wider scale phenomena.

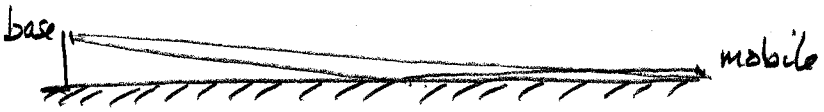


Path Loss

- In mobile, typically inverse cube or fourth power

$$P = \frac{P_o}{r^k} \qquad k = 3 - 4 \text{ or so}$$

Faster than inverse square because of interference at grazing angles of incidence



Two interfering rays, one of them reversed on reflection.

- Cell radius 100-200 m microcell
  1 — 10 km macrocell

Shadowing

- Path loss doesn't tell the whole story. Relatively local obstacles (hills, shopping or housing complexes) cause variation about the mean established by inverse k^{th} power.
- Measurements give good fit to log-normal pdf

$$x \qquad y = \ln(x) \qquad z = 10\log(x) = \frac{10}{\ln(10)}\ln(x) = X_{dB}$$

this is lognormal

these are normally distributed

With pdfs

in nat log $$p_y(y) = \frac{1}{\sqrt{2\pi}\,\sigma_y} e^{-\frac{1}{2}\left(\frac{y-\mu_y}{\sigma_y}\right)^2}$$

in dB $$p_z(z) = \frac{1}{\sqrt{2\pi}\,\sigma_z} e^{-\frac{1}{2}\left(\frac{z-\mu_z}{\sigma_z}\right)^2}$$

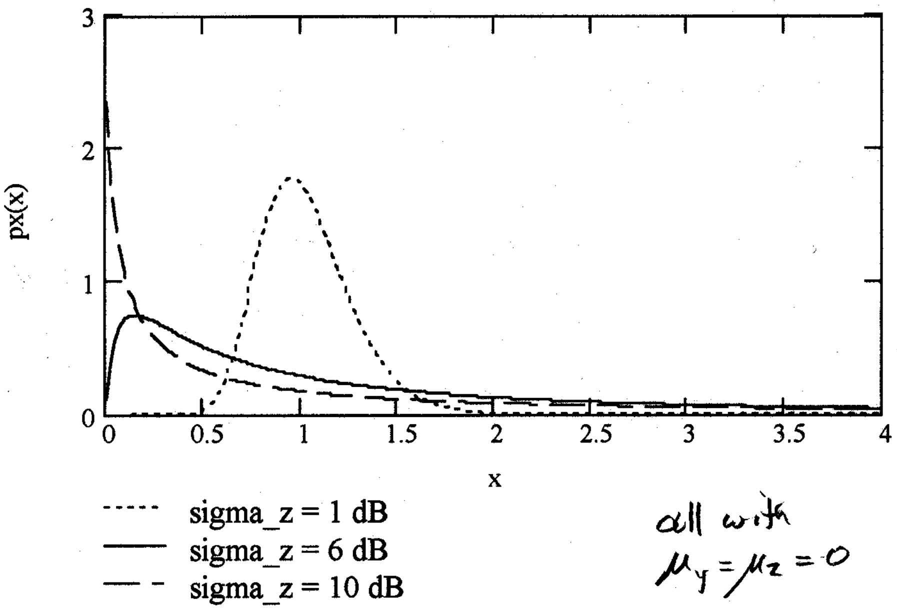
$$\mu_z = \frac{\mu_y}{0.1\ln(10)}$$

$$\sigma_z = \frac{\sigma_y}{0.1\ln(10)}$$

lognorm: $$p_x(x) = \frac{1}{\sqrt{2\pi}\,\sigma_y\, x} \exp\left(-\frac{1}{2}\left(\frac{\ln(x)-\mu_y}{\sigma_y}\right)^2\right)$$

$$= \frac{1}{\sqrt{2\pi}\,\sigma_y\, x} \exp\left(-\frac{1}{2}\left(\frac{x_{dB}-\mu_z}{\sigma_z}\right)^2\right)$$

a one-sided pdf



all with $\mu_y = \mu_z = 0$

Log-Normal Probability Density Function

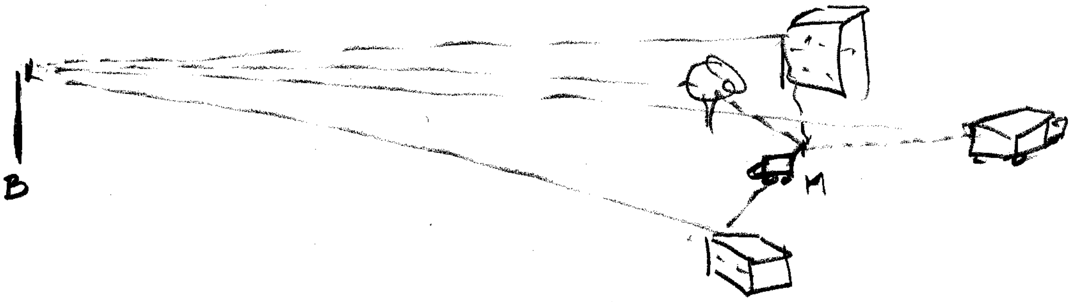
Typical measurements:

$\sigma_z \approx 6-8$ dB

- Spatial scale: significant changes over hundreds of wavelengths.

Fading

- Path loss and shadowing don't tell the whole story, either. Scattering from reflectors near the mobile produces interfering components



Do they reinforce? Do they cancel?

Could be either – but motion of the antenna in any direction by only a fraction of a wavelength changes the resultant dramatically.

- Spatial scale:
  - roughly $\lambda/2$ between successive near-nulls
  - mean square value roughly constant in a patch a few 10's of λ across.