Wireless Multimedia Systems Fall, 2008
(Topic 2)

1. **Today's topic:**

I. Finish Introduction(Modern Wireless Communication Systems)

II. Propagation and Radio System Design Issues in Mobile Radio Systems s

Reading

(A) Andersen, J.B, Rappaport, T.S, Yoshida, S. " Propagation measurements and models for wireless communication channels", IEEE Communications Magazine, Jan 1995

(B) Theodore S. Rappaport, Keith Blankenship, Hao Xu, "Propagation and Radio System Design Issues in Mobile Radio Systems for the GloMo Project", 1997

(C) The Cellular Concept

I. From a T-R transceiver point of view: (SNR)

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{9\times10^8}(e.g.900MHz)$$

$$\overline{PL}(d_0 = 1km) = 20\log_{10}(\frac{4\pi d_0}{\lambda})$$

$$P_r(d_0) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 {d_0}^2 L}$$

$$P_r(d)dBm = 10\log[\frac{P_r(d_0)}{0.001W}] + 2\times10\log(\frac{d_0}{d})$$

$$SNR(dB) = P_r(dBm) - N(dBm), SNR = P_r / N = \frac{P_t G_t G_r}{\overline{PL}} / KT_0 BF$$

$$N = -174(dBm) + 10\log_{10} B + F(dB)$$

Exercise 1: (Free Space Propagation Model)

If a transmitter produces 50 W of power, express the transmit power in units of (a) dBm, and (b) dBW. If 50 W is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna. What is Pr (10 km)? Assume unity gain for the receiver antenna.

$$P_t(dP_t(dBm) = 10\log[P_t(mW)/1mW)] = 10\log[50\times10^3] = 47.0dBm$$
$$P_t(dBW) = 10\log[P_t(mW)/1W)] = 10\log[50] = 17.0dBW$$

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} = \frac{50(1)(1)(\frac{3\times10^8}{900\times10^6})}{(4\pi)^2(100)^2(1)} = 3.5\times10^{-6}W = 3.5\times10^{-3}mW$$

$$P_r(dBm) = -24.5dBm.$$

$$P_r(d) = P_r(d_0)(\frac{d_0}{d})^2$$

$$P_r(d)dBm = 10\log[\frac{P_r(d_0)}{0.001W}] + 2\times10\log(\frac{d_0}{d}) = -24.5dBm - 40dB = -64.5dBm$$

Exercise 2: (Power Issue & Link Budget)

Maximum separation distance vs. transmitted power (with fixed BW)

- *Given*
  - Cellular phone with 0.6W transmitted power
  - Unity gain antenna, 900 MHz carrier frequency
  - SNR must be at least 25 dB for proper reception
  - Receiver BW is B=30KHz, noise figure F=10 dB
- What will be the maximum distance?
- *Solution:*
  - N= -174 dBm + 10 log 30000 + 10 dBM
  - For SNR > 25 dB, we must have Pr > (-119+25) = -94 dBm
  - Pt=0.6W = 27.78 dBm
  - This allows path loss PL(d) = Pt – Pr < 122 dB

λ = c/ f = 1/3 m

Assuming d_0 = 1 km, PL (d_0) = 91.5 dB

for free space,

n=2, so that : 122 > 91.5 + 10 * 2 log (d / 1 km))

so d < 33.5 km,

for shadowed urban with

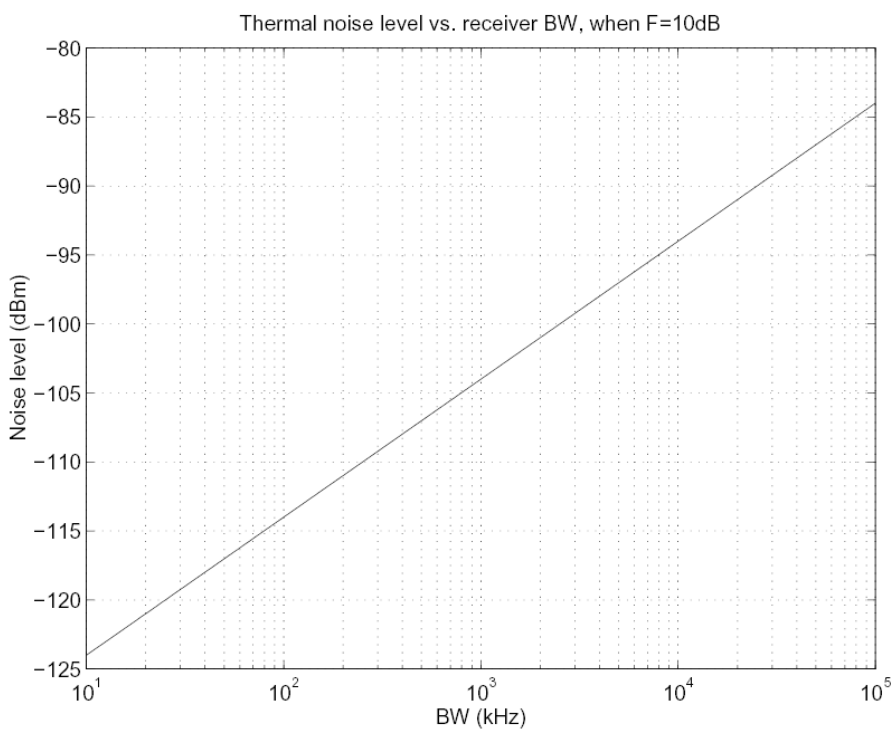
n=4, so that 122 > 91.5 + 10*4*log (d/1km))

so d < 5.8 km

a) Large Scale Path Loss Model (Link Budget Design)

(A) The noise Level (N=-174(dBm)+10$\log_{10}$B+F(dB)) vs BW

Usually, More bandwidth brings more noise.

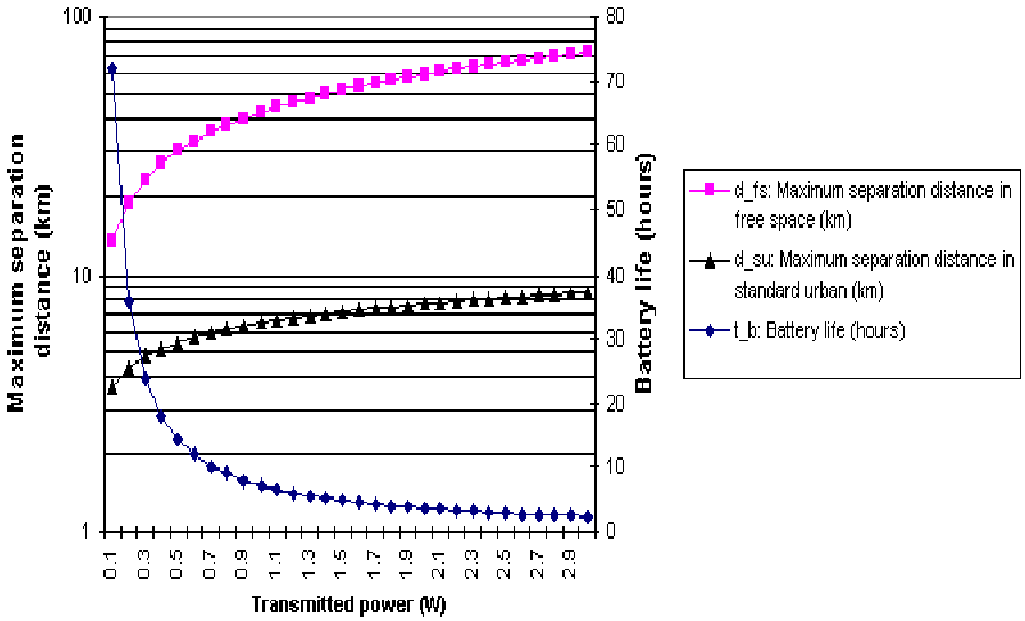


(B) Battery, Transmitted Power, Distance

More power will go for more distance. Battery life will get less.

Free space (n=2) will have more distance than shadow (N=4)

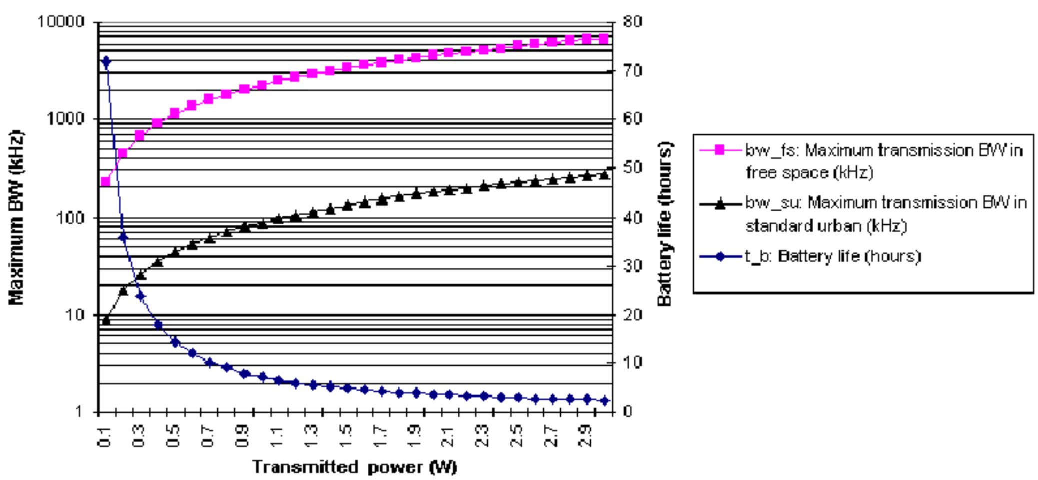
Combined plot of the maximum separation distance and the battery life vs. transmitted power, when BW= 30kHz, F=10 dB, SNR=25 dB.



(c) Bandwidth, Transmitted Power, Battery

More bandwidth will bring more noise and require more transmitted power.

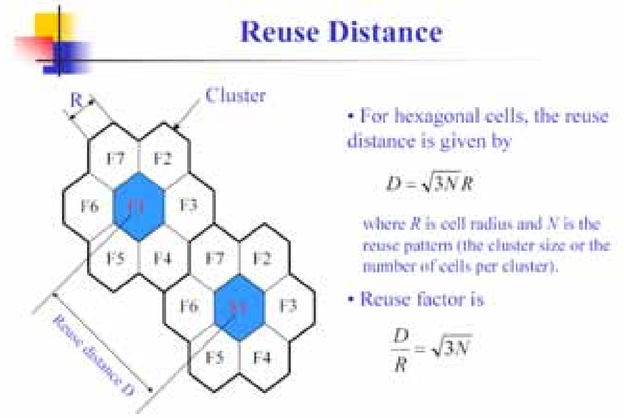
Combined plot of the battery life and the maximum transmission BW vs. the transmitted power, when d=5 km, F=10 dB, SNR=25 dB.



II. SIR (Signal to Interference Ratio, co-channel interference),

The cellular Concept/Frequency Reuse:

The same frequency will be reuse at the reuse distance D. (Co-Channel Interference)



N= 1, 3, 4, 7, 9, 12……

e.g.

- **n=4**
- **2. worst case is at D0 = R (when MH is at the fringe of its cell)**
- **3. only the six "first-tier" co-channel cells are considered**
- **4. D1 = D2 = D3 = D4= D5 = D6 = D**

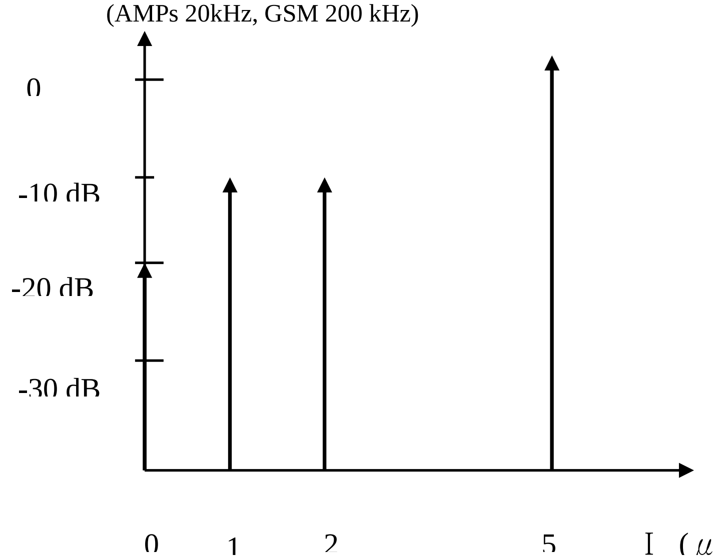
system	(C/I)min	D/R	N
AMPS	18 dB	4.6	7
GSM	11 dB	3.0	4

III. Small Scale Fading Effects

Exercise 3: Time Dispersion & Multi-path Effect

Calculate the mean excess delay, rms delay spread, and the maximum excess delay (10 dB) for the multipath profile given in the figure below. Estimate the 50% coherence bandwidth of the channel. Would this channel be suitable for AMPS or GSM service without the use of an equalizer?

(AMPs 20kHz, GSM 200 kHz)



$$\bar{\tau} = \frac{\sum_k P(\tau_k)\tau_k}{\sum_k P(\tau_k)} = \frac{(1)(5) + (0.1)(1) + (0.1)(2) + (0.01)(0)}{[0.01 + 0.1 + 0.1 + 1]} = 4.38\mu s$$

$$\overline{\tau^2} = \frac{\sum_k P(\tau_k)\tau_k^{\,2}}{\sum_k P(\tau_k)} = \frac{(1)(5)^2 + (0.1)(1)^2 + (0.1)(2)^2 + (0.01)(0)^2}{1.21} = 21.07$$

$$B_c = \frac{1}{5\sigma_\tau} = \frac{1}{5(\sqrt{21.07 - (4.38)^2}} = 146kHz$$

Exercise 4: Mobility & Doppler spread

A BS has a 900-MHz transmitter, and a vehicle is moving at the speed of 50 mph. Compute the received carrier frequency if the vehicle is moving

(a) Directly toward the BS

(b) Directly away from the BS

(c) In a direction that is 60 degrees to the direction of arrival of the transmitted signal

IV. Radio System Design Issues

Spread Spectrum: Direct Sequence and Frequency Hopping

Smart Antenna

V. Location Service

2. Next Topic: Wireless Link I: Modulation and Multiple Access