Path Loss

- Path loss is the phenomenon which occurs when the received signal becomes weaker and weaker due to increasing distance between mobile and base station. Path loss is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height and location of antennas.

Path Loss

- Path loss in decreasing order:
  - Urban area (large city)
  - Urban area (medium and small city)
  - Suburban area
  - Open area

Path Loss (Free-space)

- Definition of path loss L_P:

$$L_P = \frac{P_t}{P_r},$$

Path Loss in Free-space:

$$L_{PF}(dB) = 32.45 + 20\log_{10} f_c(MHz) + 20\log_{10} d(km),$$

where f_c is the carrier frequency.

- The higher the frequency, the higher the attenuation. It should be noted that this simple formula is valid only for land mobile radio systems close to the base station.

Free Space Propagation Model

- Predict received signal strength.
- Transmitter and receiver are in line-of-sight.
- Satellite communication and Microwave radio links undergo free space propagation.
- Large-Scale radio wave propagation models predicts the received power decays as a function of T-R distance.

Friis Free Space Equation

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

- Pt is the transmitted power.
- Pr (d) is the received power.
- Gt is the transmitter antenna gain.
- Gr is the receiver antenna gain.
- d is the T-R separation distance in meters.
- L is the system loss factor.
- λ is the wavelength in meters.

Numerical

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

Radio Propagation Models

- Also known as Radio Wave or Radio Frequency Propagation Model.
- Empirical mathematical formulation which includes:
  - Characterization of radio wave propagation
  - Function of frequency
  - Distance
  - Other condition
- Single model developed to:
  - Predict behavior of propagation
  - Formalizing the way radio waves are propagated
  - Predict path loss in the coverage area

Characteristics

- Path loss is dominant factor.
- Models typically focus on path loss realization.
- Predicting:
  - Transmitter coverage area.
  - Signal distribution representation.
- Telecommunication link encounter these conditions.
  - Terrain
  - Path
  - Obstructions
  - Atmospheric conditions
- Different model exist for different types of radio links.
- Model rely on median path loss.

Development Methodology

- Radio propagation model practical in nature.
- Means developed based on large collection of data.
- In any model the collection of data has to be sufficient large to provide enough likeliness.
- Radio propagation models do not point out the exact behavior of a link.
- They predict most likely behavior.

Variations

- Different models needs of realizing the propagation behavior in different condition.
- Types of Models for radio propagation:
  - Models for outdoor attenuations.
  - Models for indoor attenuations.
  - Models for environmental attenuations.

Models For Outdoor Attenuations

- Near Earth Propagation Models
  - Foliage Model
    - Weissberger's MED Model
    - Early ITU Model
    - Updated ITU Model
      - One Woodland Terminal Model
      - Single Vegetative Obstruction Model

Contd.

- Terrain Model
  - Egli Model
  - ITU Terrain Model
- City Model
  - Young Model
  - Okumura Model
  - Hata Model For Urban Areas
  - Hata Model For Suburban Areas
  - Hata Model For Open Areas
  - Cost 231 Model
  - Area to Area Lee Model
  - Point to Point Lee Model

Models For Indoor Attenuations

- ITU Model For Indoor Attenuations
- Log Distance Path loss Model

Models For Environmental Attenuations

- Rain Attenuation Model
  - ITU Rain Attenuation Model
  - ITU Rain Attenuation Model For Satellites
  - Crane Global Model
  - Crane Two Component Model
  - Crane Model For Satellite Paths
  - DAH Model

Okumura Model

- Used for signal prediction in Urban areas.
- Frequency range 150 MHz to 1920 MHz and extrapolated up to 3000 MHz.
- Distances from 1 Km to 100 Km and base station height from 30 m to 1000 m.
- Firstly determined free space path of loss of link.
- Model based on measured data and does not provide analytical explanation.
- Accuracy path loss prediction for mature cellular and land mobile radio systems in cluttered environment.

Formulae

$$L_{50}(\mathrm{dB}) = L_F + A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA}$$

- L_{50} = Percentile value or median value.
- L_F = Free space propagation loss.
- A_{mu} = Median attenuation relative to free space.
- $G(h_{te})$ = Base station antenna height gain factor.
- $G(h_{re})$ = Mobile antenna height gain factor.
- G_{AREA} = Gain due to the type of environment.

Correction Factor G_{AREA}

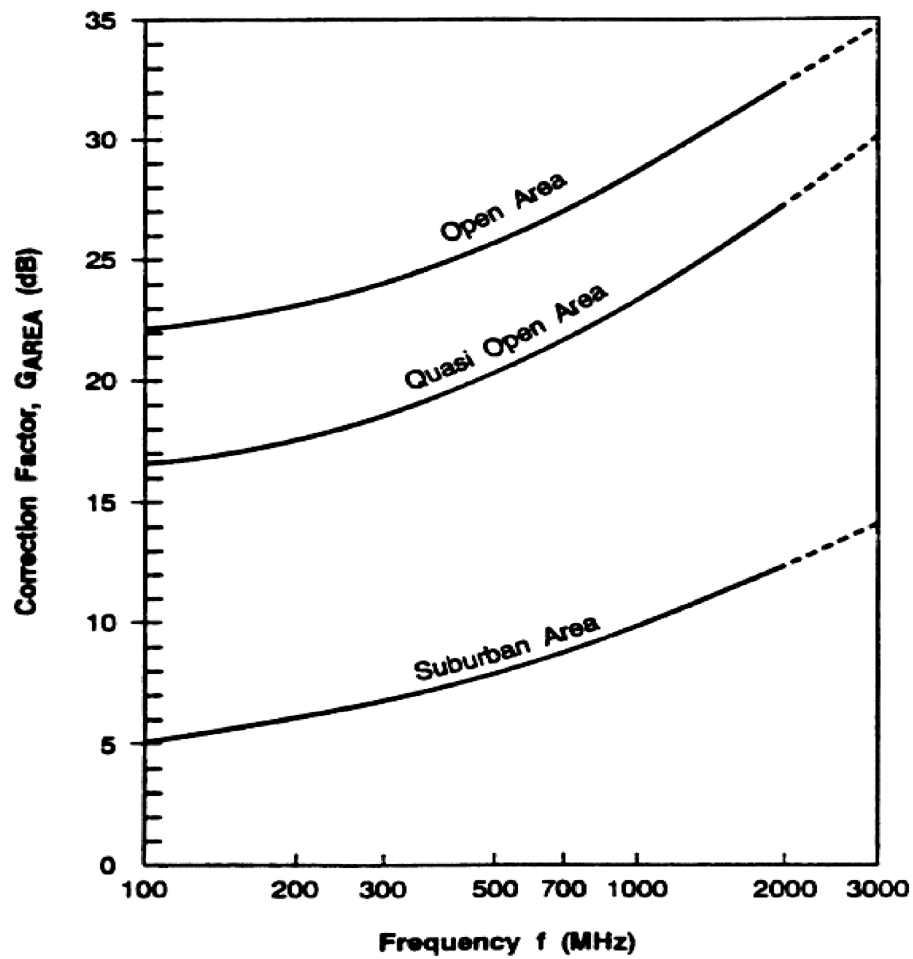

Figure 4.24 Correction factor, G_{AREA}, for different types of terrain [from [Oku68] © IEEE].

Numerical

- Find the median path loss using Okumura's model for d = 50 Km, h_{te} = 100 m, h_{re} =10m in a suburban environment. If the base station transmitter radiates an EIRP of 1 kW at a carrier frequency of 1900 MHz, find the power at the receiver (assume a unity gain receiving system). P-152

Hata Model Urban Areas

- Most widely used model in Radio frequency.
- Predicting the behavior of cellular communication in built up areas.
- Applicable to the transmission inside cities.
- Suited for point to point and broadcast transmission.
- 150 MHz to 1.5 GHz, Transmission height up to 200m and link distance less than 20 Km.

Formulae

$$L_U = 69.55 + 26.16 \log f - 13.82 \log h_B - C_H + [44.9 - 6.55 \log h_B] \log d$$

- For small or medium sized city

$$C_H = 0.8 + (1.1 \log f - 0.7) h_M - 1.56 \log f$$

- For large cities

$$C_H = \begin{cases} 8.29 (\log(1.54 h_M))^2 - 1.1 & \text{, if } 150 \leq f \leq 200 \\ 3.2 (\log(11.75 h_M))^2 - 4.97 & \text{, if } 200 < f \leq 1500 \end{cases}$$

Hata Model

- fc (Frequency in Mhz) 150 to 1500 MHz
- h_{te} (Height of Transmitter Antenna) 30 to 200m
- h_{re} (Height of Receiving Antenna) 1 to 10 m
- d (separation in T-R Km)
- C_H correction factor for effective antenna height

Numerical

- Find the median path loss using Hata model for d = 10 Km, h_{te} = 50 m, h_{re} = 5 m in a urban environment. If the base station transmitter at a carrier frequency of 900 MHz.

Hata Model For Suburban Areas

- Behavior of cellular transmission in city outskirts and other rural areas.
- Applicable to the transmission just out of cities and rural areas.
- Where man made structure are there but not high.
- 150 MHz to 1.5 GHz.

Formulae

$$L_{SU} = L_U - 2(\log \frac{f}{28})^2 - 5.4$$

- L_{SU} = Path loss in suburban areas. Decibel
- L_U = Average path loss in urban areas. Decibel
- f = Transmission frequency. MHz

Hata Model For Open Areas

- Predicting the behavior of cellular transmission in open areas.
- Applicable to the transmissions in open areas where no obstructions block the transmission link.
- Suited for point-to-point and broadcast links.
- 150 MHz to 1.5 GHz.

Formulae

$$L_O = L_U - 4.78\,(\log f)^2 + 18.33\,\log f - 40.97$$

- L_O = Path loss in open areas. Decibel
- L_U = Path loss in urban areas. Decibel
- f = Transmission frequency. MHz