Examples: Okumura-Hata, Walsh, PCS Microcell

Building heights, street widths
Parameters include antenna heights, terrain type
To estimate average received powers
Use parameters that describe propagation environment

- Parametric models
  Examples: LoS and NLoS, Ricean power
  To estimate received power
  Use topographic databases or models of transmission path

- Topographic models

Other Propagation Models
For urban clutter

- For urban areas, urban factor (\( \eta_u \)) used to account

Modifications •

- Area mode: estimates path-specific parameters
- Point-to-point mode: uses detailed terrain path profile

Modes of operation •

- Van der Pol-Bremerfar field diffraction
- Par-field scatter
- Knife-edge diffraction
- Geometric optics (i.e., 2-ray ground-reflection model)

Techniques •

Valid for f: 40 MHz – 60 GHz •

Longley-Rice/IT\S Irregular Terrain Model
buildings, multipath
- Does not predict propagation effects due to foliage,'
- Can read digital elevation map & produce signal strength contour

Advantages •

- No LOS path: (1, 2, 3, >3 directional edges)
- LOS with inadequate 1st Fresnel zone clearance (6 dB loss)
- LOS with no obstructions in 1st Fresnel zone
- Calculates paths in 3 ways
- Ignores off-radial reflections (no multipath propagation)
- Uses topographic database

Burkins Model
\[ \text{AREA}_{\varphi} - (\varphi \eta \rho \varphi) - (\varphi \eta \rho \varphi) - (p, f)^{nu} A + \varphi T = \varphi P[0 \varphi T] \]

- Add other correction factors for antenna heights and terrain from curves
- Determine median attenuation relative to free space \( A \)
- Find free space path loss, \( \varphi T \)

Technique

Based on extensive measurements

- Transmit antenna height \( \eta \): 30 m 1000m
- Distance \( d \): 1 km 100 km
- Frequency \( f \): 150 MHz 1920 MHz

Applicable for:

Widely used for signal prediction in urban areas

\textbf{Okumura Model}
sea parameter

height, isolated ridge height, average terrain slope, and mixed land.

Optional correction factors can be used, including terrain undulation.
Has been extended to 2 GHz by European Co-operative for Scientific and Technical Research (EURO-COST-231 Model) • Valid for large-cell systems, but not PCS systems and rural environments •

Similar formulas (3.87) (3.86) are available for suburban and urban coverage areas where \( a(y) \) is a correction factor for effective mobile antenna height:

\[
p' = 44.9 - 6.75 \log_{10} y + (3.87) \cdot \log_{10} p' \]

Standard formula for urban areas is

\[
y' \leftarrow 1 \text{ m} \hspace{1cm} \gamma' \leftarrow 10 \text{ m}
\]

Applicable for: \( f \): 150 MHz \( \gamma' \leftarrow 1500 \text{ MHz}, y' \leftarrow 30 \text{ m} \) to 200 m

Empirical formulation of Okumura loss data •

\[
H_{\text{ata Model}}
\]
See IS-95 CDMA and cdma2000 by Vijay George

\[ I_{sw} + I_{fs} = 0 \]

Height of reflection and antennas, and propagation distance
depends on distance between buildings, frequency,

\[ I_{sw} \] — multiscattering direction loss due to rows of buildings

\[ I_{fs} \] — receive antenna, and angle of incidence relative to street
depends on street width, frequency, height of reflection relative

\[ f \] — free space loss

Models losses in urban environment

Known as Walsh-cha-Bertoni or Walsh-cha-Ikegami Model

Walshcha Model
• Uses 2-ray ground-reflection model for LOS microcells

Wideband PCS Microcell Model

\begin{align*}
\text{n}: & 2.56 \rightarrow 2.69, \quad \text{o}: 7.67 \rightarrow 9.31
\end{align*}
In general, indoor channels are classified as LOS or NLOS. Factors include:
- Doors open or closed
- Antenna placement
- Building materials and construction
- Including sensitivity to increased variation caused by many factors in indoor environment
- Increased variation lead to more variation in signal levels
- Reflection, diffraction, scattering
- Indoor propagation is affected by the same mechanisms as outdoors

Indoor Propagation Models
Examples of same-floor losses

These losses are tabulated in tables 3.3-3.5 in the book

and between-floor losses

These partition losses are categorized into same-floor

the partitions and obstacles the signal passes through

For OBS channels, the propagation losses depend on the materials of

Measurements and Calculations
By additional floors

Note that attenuation caused by one floor > attenuation caused by additional floors

<table>
<thead>
<tr>
<th>Floors</th>
<th>Attenuation</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 floors</td>
<td>27.1 dB</td>
</tr>
<tr>
<td>4 floors</td>
<td>27.0 dB</td>
</tr>
<tr>
<td>3 floors</td>
<td>24.0 dB</td>
</tr>
<tr>
<td>2 floors</td>
<td>18.1 dB</td>
</tr>
<tr>
<td>1 floor</td>
<td>13.2 dB</td>
</tr>
</tbody>
</table>

Typical values of FAP for Office Buildings:

- FAP 915 MHZ
- FAP 1900 MHZ

FAP, Floor Attenuation Factor (in dB)

Can also quantify partition losses between floors

Losses Between Floors
<table>
<thead>
<tr>
<th>Suburban Home</th>
<th>7.0</th>
<th>0.0</th>
<th>006</th>
<th>Office, Soft Partition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Office, Hard Partition</td>
<td>9.6</td>
<td>2.4</td>
<td>006</td>
<td>Office, Hard Partition</td>
</tr>
<tr>
<td>Retail Store</td>
<td>7.0</td>
<td>3.0</td>
<td>1500</td>
<td>Building</td>
</tr>
<tr>
<td>Building</td>
<td>8.7</td>
<td>2.2</td>
<td>914</td>
<td>Frequency (MHz)</td>
</tr>
</tbody>
</table>
| $\rho$ | $\mu$ | dB | }

Typical parameter values:

Values of parameters have been measured for different types of buildings.

Log-distance path model is valid for many indoor environments.
where $u_{n}$ is the multi-floor path loss exponent

$$
\left( \frac{0^p}{p} \right)^{u_{n}} + (0^p)Td = (p)Td
$$

— eliminates $\text{FAF}$ by making path-loss exponent dependent on $# \#$ of floors

Method 2

where $u_{n} = u_{n}$

$$
\text{FAF} + \left( \frac{0^p}{p} \right)^{u_{n}} + (0^p)Td = (p)Td
$$

Method 1

Modifies log-distance model for multi-floor propagation

Attenuation-Factor Model
<table>
<thead>
<tr>
<th>Through One Floor</th>
<th>0.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through Two Floors</td>
<td>4.19</td>
</tr>
<tr>
<td>Through Three Floors</td>
<td>5.04</td>
</tr>
<tr>
<td>Through Four Floors</td>
<td>5.22</td>
</tr>
</tbody>
</table>

Typical values of nSEP, nMF:
windows

Penetration loss in front of windows \( \approx 6 \) dB

then increases

Penetration loss decreases at about 2 dB/flight until about the 9th and

Typically 7.6 \( \rightarrow \) 16.4 dB penetration loss on ground floor

Signal strength increases with height (less attenuation due to urban clutter)

**Signal Penetration into Buildings**