RF propagation (Lecture 5)

Diffraction over multiple obstructions.

* Extension of a single obstruction diffraction theory is complicated itself.
* Its analytical treatment is non-practical (requires excessive computations + requires detailed information about the TX/RX path).
* In practice, several empirical methods are suggested.
* Different methods use different accuracy.
  - usually trade-off between accuracy and complexity.

The most common approach is to model multiple obstructions as multiple knife edges. There are 2 fundamental problems:

1) Problem of identifying equivalent knife edge profile
2) Problem of deriving efficient and accurate algorithm for calculation of multiple KFD losses

1) Identification of equivalent knife edges

--- 1st way: There may be several ways how a profile

-------- 2nd way: ... can be approximated with knife edges.
In practice - there is no standard method, Vonis would determine the
location of equivalent edge in a different manner.

2) Algorithms for calculating multiple KED losses

There are several algorithms in use today

1) Ballington
2) Epstein-Parson
3) Japanese Nekurd
4) Dewar method

1) Ballington Method

- Multiple known obstacles are replaced by a single equivalent
  obstacle
- The losses associated with equivalent obstacle are calculated in accordance
  with a single KED.
- This model has low accuracy. It underpredicts in two important cases.
  - The obstacles are below loss (ignorance) = optimistic prediction
  - The obstacles are close to TX/RX = pessimism (equivalent obstacle
    becomes extremely large)
Epsilon-Peterson method

* Considers each individual obstacle.
* Total loss is sum of individual losses.
* Relatively easy to implement in software.
* Generally conservative.

\[ L_T = L_1 + L_2 + L_3 \]

- \( L_1 \): Loss from \( O_1 \) when transmitter is at \( TX \) and receiver at \( O_2 \).
- \( L_2 \): \( O_1 \) to \( O_2 \) to \( O_3 \) to \( O_2 \) to \( RX \).
- \( L_3 \): \( O_1 \) to \( O_3 \) to \( O_2 \) to \( RX \).

**Example:** Calculate the aggregate LED loss for the problem shown in the figure, using the numerical data as given in the figure and operating frequency of \( f = 800 \text{ MHz} \).

\[ \alpha = \frac{C}{f} \times \frac{8 \cdot d^6}{800 \cdot 10^6} = 0.375 \text{ dB} \]
\[ L = L_1 + L_2 \]

\[ L_1 = \frac{h_1 - l_0 x}{d_1} \Rightarrow x_1 = \frac{d_1 (h_1 - l_0 x)}{d_1 + d_2} = \frac{1000 (80 - 50)}{2000} = 15 \]

\[ d_1 = h_1 - x_1 = 75 - 15 = 60 \text{ m} \]

\[ D_1 = h_1 \sqrt{\frac{2}{\lambda} \frac{d_1 + d_2}{d_1 d_2}} = 10 \sqrt{\frac{2}{0.0375} \frac{2000}{1000 1000}} = 1.0328 \]

\[ L_1 = 20 \log \left( 0.4 - \sqrt{0.1184 - (0.38 - 0.1 \cdot 1.0328)^2} \right) = -11.1 \text{ dB} \]

\[ L_2 = \frac{h_2 - h_{ex}}{d_2} \Rightarrow x_2 = \frac{(h_2 - h_{ex}) d_2}{d_2 + d_3} \]

\[ x_2 = \frac{(75 - 25) \cdot 500}{1500} = 16.67 \]

\[ d_2 = h_2 - x_2 = 80 - 16.67 - 25 = 38.33 \text{ m} \]

\[ D_2 = d_2 \sqrt{\frac{2}{\lambda} \frac{d_2 + d_3}{d_2 d_3}} = 38.33 \sqrt{\frac{2}{0.0375} \frac{1500}{1000 500}} = 1.0328 \]
\[ L_2 = 20 \log \left( \frac{0.225}{4.88} \right) = -26.67 \]
\[ L_T = L_1 + L_2 = -14.1 \text{ dB} + (-26.67) \text{ dB} = -40.77 \text{ dB} \]

*Japanese method*

* Approach similar to Epstein-Peterson
* Difference in position of transmitter by 2nd, 3rd obstructions

\[ T' \]
\[ T'' \]
\[ T_{1,2} \]
\[ 92x \]

\[ L_T = \sum_{i=1}^{n} L_i \quad \text{number of obstructions} \]

* Deygond method*

* Seems to perform slightly better than other available methods.
* Proceed in the way zero loss are calculated:
  - Calculate the main edge
  - Divide problem into 2 smaller ones
1) Calculate \( \beta \) for each obstacle, assuming no other obstacle exists.

2) The KE with largest \( \beta \) is the main edge. Its losses are calculated as if it were a single obstacle.

3) The main edge splits the original problem into two subproblems. The process described above is repeated for these subproblems with the transmitter and receiver points on the main edge.

4) Total loss is obtained as addition of the losses from all main edges.

Theoretically, there may be as many recursion levels as the profile doubles. In practice, the recursion is carried out only to the third level.

Effective antenna height:

Plote carke, wekel.

\[ \text{PL[dB]} = 20 \text{dB} + 30 \log_2 \text{MHz} - 20 \log_2 \text{loss} \]

\* Various of \( \text{MHz} \) are usually small.

\* Base station heights vary substantially.

\* In practice, the base station height correction is derived with respect to.
1. Absolutes used.

2. Average used (HAAT).

\[ \text{Delta} = \text{const} \times \log \left( \frac{\text{base}}{\text{height}} \right) \]

1) Absolute used.

2) Average used.

\[ \text{HAAT} = \text{hirs} - \text{lat average} \]
HAAT is used frequently, especially in models that are derived from Hohn/Okumura propagation models.

* On average, this type of channel performs relatively well.
* It fails to respond to rapid changes in terrain profile.

Due to averaging, the model misses the fast but unstable is severely abstracted.

3) Relative method

\[ \text{Loss} = \begin{cases} \text{ltTX} + \text{ltRX} - \text{limo}, & \text{ltTX} > \text{ltRX} \\ \text{ltRX}, & \text{ltTX} \leq \text{ltRX} \end{cases} \]

- ltTX = Height of the transmission above local ground
- ltRX = Height of the receiver base above sea level
- limo = Height of the mobile above sea level
4) Slope unobscured

* Extend the slope of the local terrain to the intersection of the transmitter axis.
* Calculate base as the point of transmitter height above the intersection point.
* If the terrain is sloping up, results in considerable gain.
* If the terrain is sloping up, results in loss of the signal.
* Well suited for vertical polarization.
* Responds quickly to changes in local terrain.
* Its implementation requires accurate terrain resolution.

**Example.** Calculate effective antenna height correction for scenario in figure. Use slope method and assume $C_L = 15 \text{ dB/dec}$, $h_{id} = 50 \text{ m}$.

$$h_{re} = 30 \text{ m}$$

$$\Delta h = h_{id} - h_{se} = 20 \text{ m}$$

$$\tan \alpha = \frac{\Delta h}{d_2} = \frac{h_{re} - h_{id}}{d_1}$$ (1)

$$d_1 + d_2 = \theta$$

(2)
(1) \[ d_2 = \frac{\Delta L}{\tan \theta} = \frac{20 \mu}{\tan \left( 10 \frac{\text{ft}}{180} \right)} = 113.42 \mu \]

(2) \[ d_1 = d - d_2 = 300 - 113.42 = 186.58 \mu \]

(3) \[ L_{\text{req}} = L_{\text{Rx}} + d_1 \cdot \tan \alpha = 30 \mu + 186.57 \cdot \tan \left( 10 \frac{\text{ft}}{180} \right) = 62.89 \mu \]

\[ \Delta G = 15 \log \left( \frac{L_{\text{req}}}{L_{\text{Rx}}} \right) = 15 \log \left( \frac{62.89}{30} \right) = 1.49 \text{ dB} \]

**Prediction of the Termin Database**

Termin is represented as an array of brightness:

![Termin array diagram](image)

- One bin (pixel) represents a termin resolution ~ 30 - 250 \mu
RF pulse prediction is 3-D problem.
In most practical applications, it is modeled as 2D.
(Note there are some models that implement 3D prediction approaches.)
Transform from 3-D to 2-D is accomplished through pseudo profile.
Most propagation models predict the pulse loss based on the radio profile only.
less of some information is fundamental limit on model accuracy.

Bin size (resolution)

There is a tradeoff between accuracy and bin size. In general, using bins of smaller size contributes to more accurate tensor representation. As a result, models predict more accurately. However, if the bin size is decreased below a certain point, the pulse loss becomes dominated by small-scale effects, and difference between predictions and measurement increases.

\[ \Delta E_{\text{err}} = E_0 \left( \text{prediction} - \text{true value} \right)^2 \]

- Small scale: prop. effects
- Inst. accurately accurate tensor
- Decrease of computational requirements \( \propto \frac{1}{n^2} \)
- Optimum resolution
- Bin size [cm]

Optimum tensor resolution is a function of terrain ruggedness. More rugged terrain \( \Rightarrow \) smaller bins.
Summary so far:

1) propagation in free space (no terrain effects)
2) propagation over flat Earth
3) log distance path model
4) Effects of the terrain
   - diffraction
   - corrections
   - Effective antenna height

\[ \text{macroscopic propagation models.} \]