Hata Model

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Motivation

Since the mid 1990's the cellular communications industry has witnessed rapid growth. Wireless mobile communication networks have become much more pervasive than anyone ever imagined when cellular concept was first developed. High quality and high-capacity networks are in need today, estimating coverage accurately has become exceedingly important. Therefore, for more accurate design coverage of modern cellular networks, measurement of signal strength must be taken into consideration, thus, to provide efficient and reliable coverage area.

From the beginning of the 20th century onwards research has been going on to provide new methods and products for wireless communication in order to exchange multimedia information. High quality and high-capacity networks are in need today, for that estimating coverage accurately has become exceedingly important. Therefore, for more accurate design coverage of modern cellular networks, measurement of signal strength must be taken into consideration, thus providing efficient and reliable coverage area. The nature of the radio channel affects the transmission of information through it. One of the major challenges facing engineers in mobile radio design has been modeling an accurate radio channel and its characteristics. The electromagnetic wave propagation can generally be attributed to scattering, diffraction and reflection. Because of multiple reflections from various objects, they travel along different paths of varying lengths. Most cellular radio systems operate in urban areas where there is no direct line-of-sight path between the transmitter and receiver and there is presence of high-rise buildings causing severe diffraction loss.

Aim/Objective

Path loss determination using Hata model and its implementation in MATLAB

Introduction

Mobile radio communications in cellular radio take place between a fixed base station (bs) and several roaming mobile stations (ms). From the research that has been taken place over the years, those involving characterization and modeling of the radio propagation channel are amongst the most important and fundamental. The propagation channel is the principal contributor to many problems and limitations of the best mobile radio systems. One obvious example is multipath propagation which is the major characteristic of mobile radio channels. It is caused by diffraction and scattering from terrain features and buildings, that leads to distortion in analogue communication systems and severely affects the performance of digital systems by reducing the carrier-to-noise and carrier-to-interference ratios. A physical understanding of mathematical modeling of the channel is very important because it facilitates more accurate prediction of system performance and provides the mechanism to test and evaluate methods to see the effects caused by the radio channel.

Outdoor propagation models involve estimation of propagation loss over irregular terrains such as mountainous regions, simple curved earth profile, etc., with obstacles like trees and buildings. All such models predict the received signal strength at a particular distance or on a small sector. These models vary in approach, accuracy and complexity. Hata Okumura model is one such model.

Design

In 1968, Dr.Yoshihisa Okumura traveled around Tokyo city and made measurements for the signal attenuation from base station to mobile station. He came up with a set of curves which gave the median attenuation relative to free space path loss. Okumura came up with three sets of data for three scenarios: open area, urban area and sub-urban area. Since this was one of the very first models developed for cellular propagation environment, there exist other difficulties and concerns related to the applicability of the model.

The Hata model (1980) is a radio propagation model that works for microwave frequencies between 150 and 1500 MHz and predicts the path loss of cellular communications in outdoor settings. It is also known as the Okumura-Hata model since it is an empirical formulation based on information from the Okumura model. The model uses graphical data input from the Okumura model to represent the effects of diffraction, reaction, and scattering brought on by urban structures. The Hata Model also adjusts for use in suburban and rural settings.

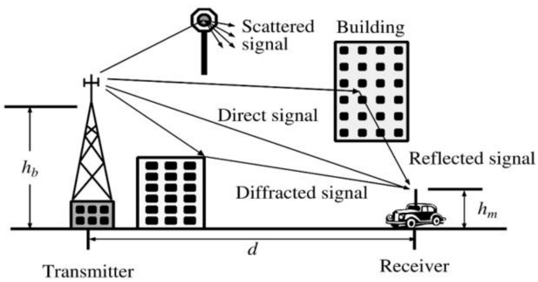

Fig 1: Mobile radio communication environment

Methodology

Despite being based on the Okumura model, the Hata model does not cover the entire spectrum of frequencies that the Okumura model does. While Okumura has compatibility for up to 1920 MHz, the Hata model only goes as high as 1500 MHz. The model is appropriate for both point-to-point and broadcast communications, and it includes link distances of 1–10 km and mobile station antenna heights of 1–10 m, 30–200 m, and base station antenna heights of 30–200 m.

Urban Environments

Since it was based on measurements taken by Okumura in Tokyo's built-up areas, the Hata model for urban environments serves as the fundamental formulation. It is expressed as follows:

$$L_U = 69.55 + 26.16 \log_{10} f - 13.82 \log_{10} h_B - C_H + [44.9 - 6.55 \log_{10} h_B] \log_{10} h_B$$

For small or medium-sized city,

$$C_H = 0.8 + \left(1.1 \log_{10} f - 0.7\right) h_M - 1.56 \log_{10} f$$

For Large cities,

$$C_H = \begin{cases} 8.29(\log_{10}(1.54 h_M))^2 - 1.1\,, if\ 150 \le f \le 200 \\ 3.2(\log_{10}(11.75 h_M))^2 - 4.97\,, if\ 2000 \le f \le 1500 \end{cases}$$

where

L_U = Path loss in urban areas. Unit: decibel (dB)
h_B = Height of base station antenna. Unit: meter (m)
h_M = Height of mobile station antenna. Unit: meter (m)
f = Frequency of transmission. Unit: Megahertz (MHz)
C_H = Antenna height correction factor
d = Distance between the base and mobile stations. Unit: kilometer (km)

Suburban Environments

The transmissions just outside of cities and on rural areas where man-made structures are present but not as high and dense as in the cities are both applicable to the Hata model for suburban environments. To be more specific, this concept works well in areas with buildings if the mobile station's height does not significantly vary. It is expressed as follows:

$$L_{SU} = L_U - 2\left(\log_{10}\frac{f}{28}\right)^2 - 5.4$$

where

L_{SU} = Path loss in suburban areas. Unit: decibel (dB)
L_U = Path loss from the small city version of the model (above). Unit: decibel (dB)
f = Frequency of transmission. Unit: Megahertz (MHz)

Open Environments

The Hata model for rural environments is applicable to transmissions in open areas where no obstructions block the transmission link. It is expressed as:

$$L_O = L_U - 4.78(\log_{10} f)^2 + 18.33(\log_{10} f) - 40.94$$

where

L_O = Path loss in open areas. Unit: decibel (dB)
L_U = Average path loss from the small city version of the model (above). Unit: decibel (dB)
f = Frequency of transmission. Unit: megahertz (MHz)

MATLAB Code

```
clc;
close all;
clear all;
hte= 39 %hte= height of transmitting antenna
hre = 2 %hre= height of receiving antenna
fc=159; % in MHz
d=8
t= 1 %loss of t=1 for urban environment
loss = zeros(1,4)
k=1;
% a = ch
for fc= 100:500:1600
if (t==1) % urban area city
a= (1.1*log(fc)-0.7)*hre-(1.56*log(fc)-0.8); % Antenna height correction factor
else if (fc <200)
```

```
a = 8.29*power(log(1.54*hre),2)-1.1;
else
a=3.2*(log(11.574*hre)^2)-4.97;
end
end
lurban=69.55+26.16*log(fc)-13.86*log(hte)-a+(44.9-6.55*log(hte))*log(d);
loss_lurban(k)= lurban
lsub= lurban-2*(log(fc/28)^2)-5.4;
% for suburban area
loss_lsub(k)= lsub
% for rural area
lrural = lurban - 4.78*power(log(fc),2)+18.33*log(fc)-40.94;
loss_lrural(k)= lrural
k=k+1;
end
%plot between freq and loss
fc= 100:500:1600
% plot for urban area 6

figure
plot(fc,loss_lurban)
xlabel('Frequency(MHz)')
ylabel('Path loss(dB)')
title('Hata Model(Urban Area)')
figure
plot(fc,loss_lsub)
xlabel('Frequency(MHz)')
ylabel('Path loss(dB)')
title('Hata Model(Sub-Urban Area)')
figure
plot(fc,loss_lrural)
xlabel('Frequency(MHz)')
ylabel('Path Loss(dB)')
title('Hata Model(Rural Area)')
```

Simulation (The Output of the MATLAB Code)

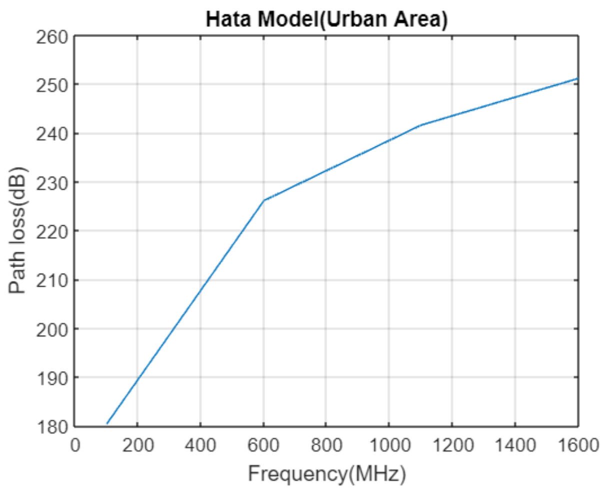

Fig 2a: The Path Loss trend in Urban areas using the HATA Model

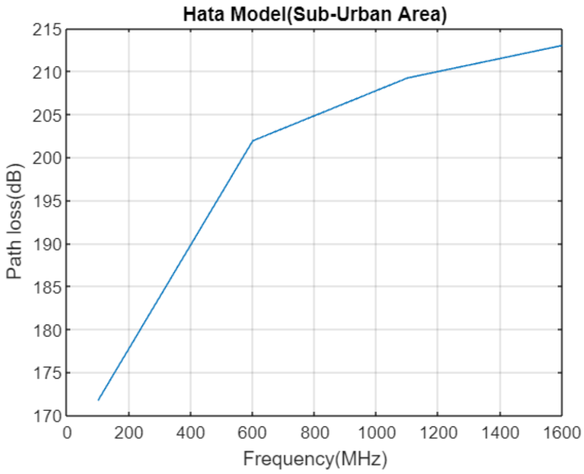

Fig 2b: The Path Loss trend in Sub-Urban areas using the HATA Model

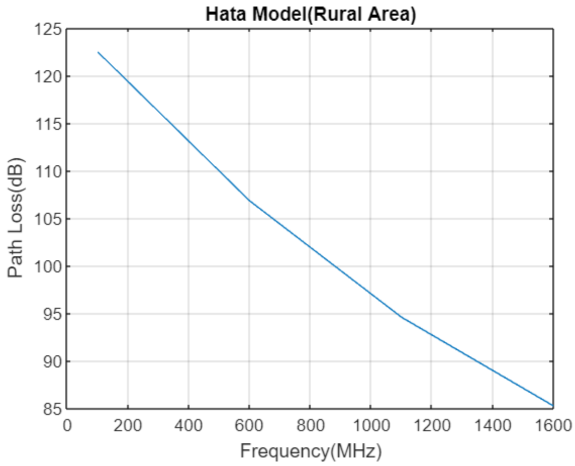

Fig 2c: The Path Loss trend in Rural areas using the HATA Model

Analysis

As per the given input, the parameters were considered and the plot for the Path loss trend based on Hata model for various kinds of terrains was obtained. The Hata model is an empirical formulation of the graphical path-loss data provided by the Okumura and is valid over roughly the same range of frequencies, 150-1500MHz. This empirical formula simplifies the calculation of path loss because it is a closed form formula and it is not based on empirical curves for the different parameters. The usage and accuracy of this prediction model depends on the propagation environment.

Conclusion

Generally, this work was focused on predicting the mean signal strength in different areas and with the signal variability as the mobile moves. It is to be noted that most propagation models aim to predict the median path loss. However, existing predictions models differ in their applicability over different terrain and environmental conditions. Although there are many predictions methods based on deterministic processes through the availability of improved databases. However, Hata model is corner stoned on Okumura‟s theatre of operations test termination and predicted various equality for way of life going with different types of welters.

Result (Values obtained from the MATLAB Code)

```
hte =

    39

hre =

     2

d =

     8

t =

     1

loss =

     0     0     0     0

loss_lurban =

  180.3649

loss_lsub =

  171.7241

loss_lrural =

  122.4654

loss_lurban =

  180.3649  226.0906

loss_lsub =

  171.7241  201.9056

loss_lrural =

  122.4654  106.8054
```

```
loss_lurban =

  180.3649  226.0906  241.5592


loss_lsub =

  171.7241  201.9056  209.2088


loss_lrural =

  122.4654  106.8054   94.5602


loss_lurban =

  180.3649  226.0906  241.5592  251.1214


loss_lsub =

  171.7241  201.9056  209.2088  212.9884


loss_lrural =

  122.4654  106.8054   94.5602   85.2340


fc =

         100         600        1100        1600
```

Scope

The robustness and the viability of the Okumura-Hata Model has led to the development of further derivative models utilized in specific applications. Namely, the COST Hata Model is a direct derivative of the HATA Model developed by the European Cooperation in Science and Technology COST (COopération européenne dans le domaine de la recherche Scientifique et Technique) based on experimental measurements in multiple cities across Europe. The main advantage of this model is that it covers a more elaborate range of frequencies (up to 2 GHz). This model is applicable to macro cells in urban areas. To further evaluate Path Loss in suburban or rural (quasi-)open areas, this path loss must be substituted into Urban to Rural / Urban to Suburban Conversions. The only disadvantage of this model is that it requires that the base station antenna is higher than all adjacent rooftops.

The parameters considered for this model are listed as follows:
Frequency: 1500–2000 MHz
Mobile station antenna height: 1–10 m
Base station antenna height: 30–200 m
Link distance: 1–20 km

$$L_b = 46.3 + 33.9\log_{10}\frac{f}{\mathrm{MHz}} - 13.82\log_{10}\frac{h_B}{\mathrm{m}} - a(h_R, f) + \left(44.9 - 6.55\log_{10}\frac{h_B}{\mathrm{m}}\right)\log_{10}\frac{d}{\mathrm{km}} + C_m$$

Where,
L_b Median path loss. Unit: decibel (dB)
f Frequency of Transmission. Unit: megahertz (MHz)
h_B Base station antenna effective height. Unit: meter (m)
d Link distance. Unit: Kilometer (km)
h_R Mobile station antenna effective height. Unit: meter (m)

For suburban or rural environments this factor is defined as,

$a(h_R, f)$

$$a(h_R, f) = \left(1.1\log_{10}\frac{f}{\mathrm{MHz}} - 0.7\right)\frac{h_R}{\mathrm{m}} - \left(1.56\log_{10}\frac{f}{\mathrm{MHz}} - 0.8\right)$$

For suburban or rural environments this factor is defined as,

$$a(h_R, f) = \begin{cases} 8.29(\log_{10}(1.54h_R))^2 - 1.1 & ,\text{if } 150 \le f \le 200 \\ 3.2(\log_{10}(11.75h_R))^2 - 4.97 & ,\text{if } 200 < f \le 1500 \end{cases}$$

Constant offset. Unit: decibel (dB). Defined as,

C_m

$$C_m = \begin{cases} 0\ dB & \text{for medium cities and suburban areas} \\ 3\ dB & \text{for metropolitan areas} \end{cases}$$

Further on there are numerous other models derived from the Hata Model. Such as the HATA PCS extension which is an extended version of the COST Hata Model.

Acknowledgment

I would like to express my sincerest gratitude to my teacher Prof. Pooja Mohnani for providing this opportunity and guidance and support given throughout this development work. I got to learn a lot more about this project about the impact of path loss models which will be very helpful for me in my endaevours. Finally, I would like to thank my parents and friends who have helped me with their valuable suggestions and guidance and have been very helpful in various stages of project completion.

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