NIST
National Institute of
Standards and Technology
U.S. Department of Commerce

CTL Communications Technology Laboratory

# Extended Hata Propagation Model Code

# TUTORIAL


U.S. Department of Commerce

National Institute of Standards and Technology

Communications Technology Laboratory

Wireless Networks Division (673)


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# 1 Introduction

The purpose of this tutorial is to provide instructions on how to use a set of MATLAB functions to predict individual links' propagation losses of the extended Hata propagation model.

# 2 MATLAB Code Tutorial

## 2.1 Required MATLAB products

The following MATLAB products are required in order to run the MATLAB code:

- MATLAB
- Signal Processing Toolbox
- Statistics Toolbox

## 2.2 Code Structure

There are 9 MATLAB functions (*.m files) are located in the root folder ('*eHATA/*'). 8 functions ('*ExtendedHata_*.m*') were implemented specifically for the extended Hata propagation model and 1 function ('*piecelin.m*') was downloaded from www.mathworks.com to get piecewise linear interpolation. For each of the m-files, description, inputs, and outputs are documented at the beginning of the file. The folder '*eHATA/tests*' contains 8 MATLAB scripts and a (.mat) data file used to test each function individually. The folder '*eHATA/doc*' contains a short tutorial, e.g. this document, in both Words and PDF formats.

## 2.3 Adding the code to the path

To be able to use the functions stored in a certain folder, one needs to specify where the code is located, for example:

```
>> addpath('C:\MATLAB\eHATA')
```

This will add the indicated directory to the MATLAB search path.

## 2.4 Compute Median Basic Transmission Loss

The function '*ExtendedHata_MedianBasicPropLoss.m*' is used to predict the median basic transmission loss the extended Hata model. The median basic transmission loss is intended for use in quasi-smooth terrain and it is independent of site-specific terrain data. For more details of the equations implemented in the function can be found in [1-4].

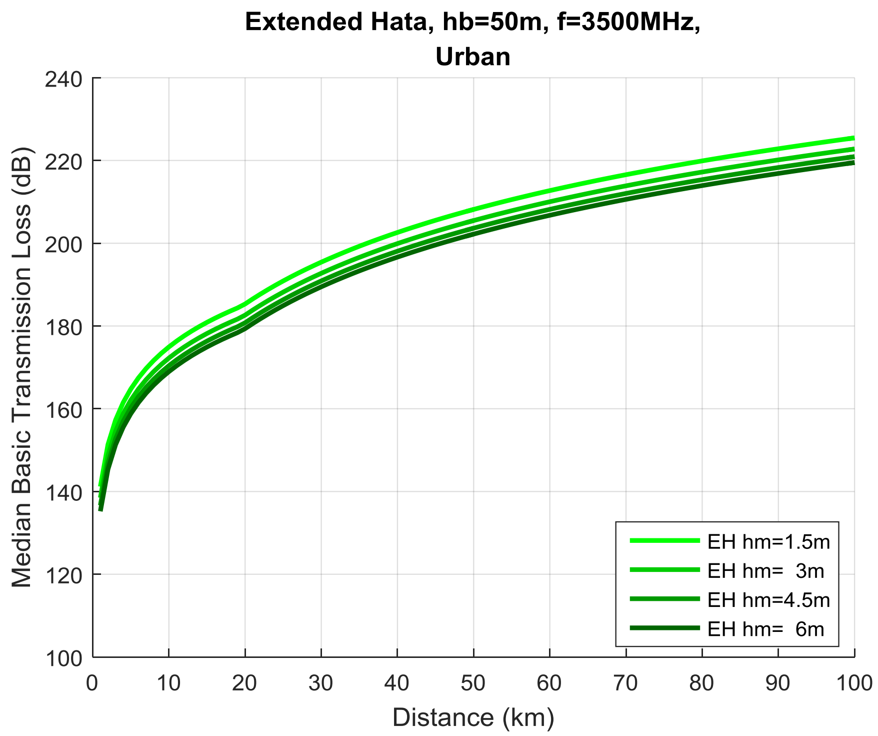
To run this function, enter the command below at the prompt:

```
>> [MedianLossEH, MedianAbmEH] =
ExtendedHata_MedianBasicPropLoss(f, d, hb, hm, region);
```

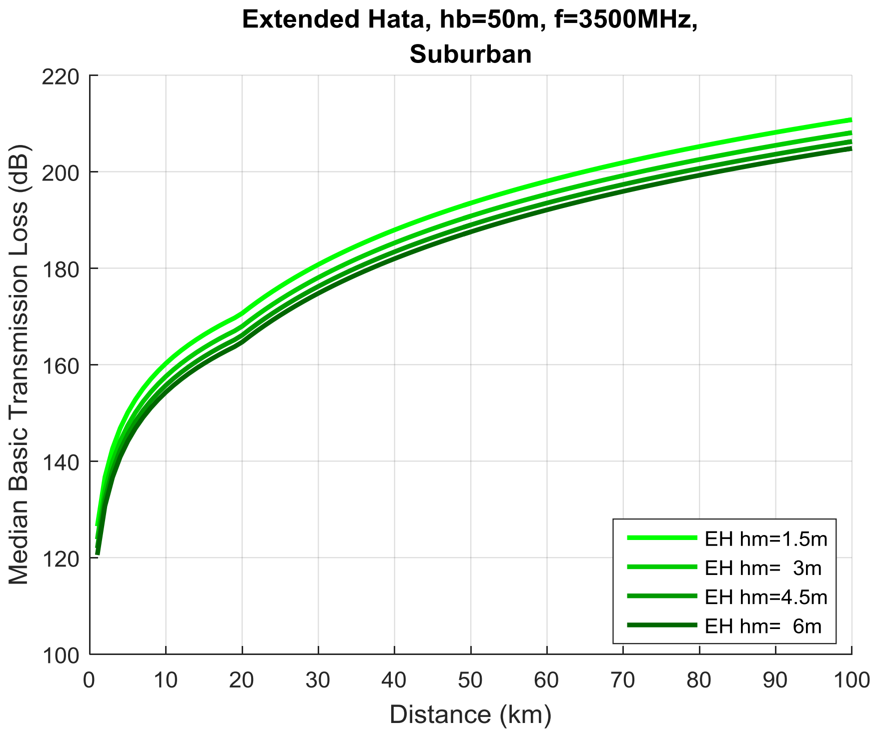
Where:

| | Parameter | Description |
|---|---|---|
| **Input** | f | frequency (in MHz), in the range of [1500, 3000] MHz |
| | d | distance (in kilometers) between the base station and mobile, in the range of [1, 100] km |
| | hb | antenna height (in meters) of the base station, in the range of [30, 200] m |
| | hm | antenna height (in meters) of the mobile station, in the range of [1, 10] m |
| | region | region of the area ('DenseUrban', 'Urban', 'Suburban') |
| **Output** | MedianLossEH | median basic transmission loss (in decibels) |
| | MedianAbmEH | basic median attenuation relative to free space (in decibels) |

For example, Figure below shows the median basic propagation loss, LossEH, in an 'Urban' region for f = 3,500 MHz, 1 km ≤ d ≤ 100 km, $h_b$ = 50 m, and $h_m$ = [1.5, 3, 4.5, 6] m.




Similarly, Figure below shows the median basic propagation loss, LossEH, in a 'Suburban' region for f = 3,500 MHz, 1 km ≤ d ≤ 100 km, $h_b$ = 50 m, and $h_m$ = [1.5, 3, 4.5, 6] m.




These results are similar to the results presented by NTIA, ITS at:

http://www.its.bldrdoc.gov/media/66168/mckenna_presentation_20150513.pdf

## 2.5 Compute Site-Specific Correction Factors

In addition to the median basic transmission loss, the extended Hata model also implement various site-specific corrections to be applied to the median loss curves. These correction factors depend on terrain data of each individual path and they are used in situations where the terrain data becomes irregular and rugged.

### 2.5.1 Effective Height Corrections

The function '*ExtendedHata_EffHeightCorr.m*' is used to compute terminals' effective height corrections (for both base station and mobile). More details of the definition and calculation method can be found in [1-2].

To run this function, enter the command below at the prompt:

```
>> [hb_eff_m, hm_eff_m] = ExtendedHata_EffHeightCorr(hb_ant_m,
hm_ant_m, elev);
```

Where:

| | Parameter | Description |
|---|---|---|
| **Input** | hb_ant_m | antenna height (in meters) of the base station |
| | hm_ant_m | antenna height (in meters) of the mobile station |

| | | |
|---|---|---|
| | elev | an array contains elevation profile between base station and mobile, where<br>• elev(1) = numPoints – 1 (where numPoints is the number of points between Tx & Rx)<br>• elev(2) = distance between points (in meters). Thus, elev(1)- 1)*elev(2)=distance between Tx & Rx)<br>• elev(3) = Tx elevation (in meters) elev(numPoints+2) = Rx elevation (in meters) |
| **Output** | hb_eff_m | effective transmitting antenna height (in meters) of the base station |
| | hm_eff_m | effective receiving antenna height (in meters) of the mobile station |

### 2.5.2 Median and Fine Corrections for Rolling Hilly Terrain

The function '*ExtendedHata_RollingHillyCorr.m*' is used to compute "median", "fine", and "total" rolling hilly terrain corrections (applied to the vicinity of the mobile station only). More details of the definition and calculation method can be found in [1-2].

To run this function, enter the command below at the prompt:

```
>> [Krh, Kh, Khf] = ExtendedHata_RollingHillyCorr(elev);
```

Where:

| | Parameter | Description |
|---|---|---|
| **Input** | elev | an array contains elevation profile between base station and mobile |
| **Output** | Krh | total correction factor for rolling hilly terrain (in decibels), where Krh = Kh - Khf |
| | Kh | "median" correction factor for rolling hilly terrain (in decibels) |
| | Khf | "fine" correction factor for rolling hilly terrain (in decibels) |

### 2.5.3 General Slope of Terrain Correction

The function '*ExtendedHata_GeneralSlopeCorr.m*' is used to compute the general slope of terrain correction (applied to the vicinity of the mobile station only). More details of the definition and calculation method can be found in [1-2].

To run this function, enter the command below at the prompt:

```
>>  Kgs = ExtendedHata_GeneralSlopeCorr(elev);
```

Where:

| | Parameter | Description |
|---|---|---|
| **Input** | elev | an array contains elevation profile between base |

| | | |
|---|---|---|
| | | station and mobile |
| **Output** | Kgs | correction factor for general slope (in decibels) |

### 2.5.4 Isolated Mountain (or Isolated Ridge) Correction

The function '*ExtendedHata_IsolatedRidgeCorr.m*' is used to compute the isolated ridge correction factor (applied to the vicinity of the mobile station only). More details of the definition and calculation method can be found in [1-2].

To run this function, enter the command below at the prompt:

```
>>  Kir = ExtendedHata_IsolatedRidgeCorr(elev);
```

Where:

| | Parameter | Description |
|---|---|---|
| **Input** | elev | an array contains elevation profile between base station and mobile |
| **Output** | Kir | correction factor for isolated ridge (in decibels) |

### 2.5.5 Mixed Land-Sea Path Correction

The function '*ExtendedHata_MixedPathCorr.m*' is used to compute the mixed land-sea path correction factor. More details of the definition and calculation method can be found in [1-2].

To run this function, enter the command below at the prompt:

```
>>  Kmp = ExtendedHata_MixedPathCorr(elev);
```

Where:

| | Parameter | Description |
|---|---|---|
| **Input** | elev | an array contains elevation profile between base station and mobile |
| **Output** | Kmp | correction factor for mixed land-sea path (in decibels) |

### 2.5.6 Location Variability Estimate

The function '*ExtendedHata_LocationVariability.m*' is used to compute the estimate of the standard deviation of the location variability for urban and suburban environments. More details of the definition and calculation method can be found in [1].

To run this function, enter the command below at the prompt:

```
>> sigma = ExtendedHata_LocationVariability(freq_MHz, region);
```

Where:

| | Parameter | Description |
|---|---|---|
| **Input** | freq_MHz | frequency (in MHz), in the range of [1500, 3000] MHz |
| | region | region of the area ('DenseUrban', 'Urban', 'Suburban'). Note that 'DenseUrban' is considered as 'Urban' |
| **Output** | sigma | standard deviation of the location variability (in decibels) |

## 2.6 Compute Total Path Loss

The function '*ExtendedHata_PropLoss.m*' is the main function used to adjust the median basic transmission loss with the site-specific correction factors as well as location variability computed in the previous steps. For more details of the equations used in the function can be found in [1-4].

To run this function, enter the command below at the prompt:

```
>> LossEH = ExtendedHata_PropLoss(freq_MHz, hb_ant_m, hm_ant_m,
region, elev);
```

Where:

| | Parameter | Description |
|---|---|---|
| **Input** | freq_MHz | frequency (in MHz), in the range of [1500, 3000] MHz |
| | hb_ant_m | antenna height (in meters) of the base station, in the range of [30, 200] m |
| | hm_ant_m | antenna height (in meters) of the mobile station, in the range of [1, 10] m |
| | region | region of the area ('DenseUrban', 'Urban', 'Suburban') |
| | elev | an array contains elevation profile between base station and mobile |
| **Output** | LossEH | total propagation loss (in decibels) |

# 3 Acknowledgements

The development of the code is supported under the Spectrum Sharing Research Program at the National Institute of Standards and Technology (NIST), Communications Technology Laboratory (CTL), Wireless Networks Division. This code was developed independently by NIST employees in consultation with the National Telecommunications and Information Administration (NTIA), Institute for Telecommunication Sciences (ITS). The NTIA may release an official version used in the NTIA Report 15-517 later.

# 4 References

[1] U.S. Department of Commerce, National Telecommunications and Information Administration, 3.5 GHz Exclusion Zone Analyses and

Methodology (Jun. 18, 2015), available at http://www.its.bldrdoc.gov/publications/2805.aspx.

[2] Y. Okumura, E. Ohmori, T. Kawano, and K. Fukuda, Field strength and its variability in VHF and UHF land-mobile radio service, Rev. Elec. Commun. Lab., 16, 9-10, pp. 825-873, (Sept.-Oct. 1968).

[3] M. Hata, Empirical formula for propagation loss in land mobile radio services, IEEE Transactions on Vehicular Technology, VT-29, 3, pp. 317-325 (Aug. 1980).

[4] Anita G. Longley, Radio Propagation in Urban Areas, United States Department of Commerce, Office of Telecommunications, OT Report 78-144 (Apr.1978), available at http://www.its.bldrdoc.gov/publications/2674.aspx.