



**Department of Electronics and Communications Engineering**

**COMPARATIVE ANALYSIS OF OKUMURA-HATA  
AND COST 231 PATH LOSS MODELS FOR  
WIRELESS MOBILE COMMUNICATIONS**

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# Letter of Transmittal

To  
Md. Asif Hossain  
Assistant Professor  
Department of Electronics and Communication Engineering  
East West University

**Subject: Submission of Project Report as (ICE-498)**

Dear Sir,

We are pleased to let you know that we have completed our thesison “**Comparative Analysis of Okumura-Hata and COST 231 Path Loss Models for Wireless Mobile Communications**”. The attachment contain of the thesis that has been prepared for your evaluation and consideration. Working on this thesis has given us some new concepts. By applying those concept we have tried to make something innovative by using our theoretical knowledge which we have acquired since last four years from you and the other honorable faculty members of EWU. This thesis would be a great help for us in future.

We are very grateful to you for your guidance, which helped us a lot to complete my project and acquire practical knowledge.

Thanking You.

Yours Sincerely

Eliza Khatun

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# Declaration

This is certified that the project is done by us under the course “Thesis (ICE-498)”. The thesis of **“Comparative Analysis of Okumura-Hata and COST 231 Path Loss Models for Wireless Mobile Communications”** has not been submitted elsewhere for the requirement of any degree or any other purpose except for publication.

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# Acceptance

This thesis paper is submitted to the **Department of Electronics and Communications Engineering, East West University** is submitted in partial fulfillment of the requirements for the degree of **B.Sc. in Information & Communications Engineering** under complete supervision of the undersigned.

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**Md. Asif Hossain**  
Assistant Professor  
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# **Abstract**

Wireless mobile communication is key factor the next generation communication systems. But it faces several impairments in transmission such as attenuation, fading, distortion and absorption. Path loss is happened due to these problems. To minimize such path loss in transmission, different path loss models have been used. This project deals with the two prominent empirical path loss models: Okumura-Hata and COST 231. Various operating frequencies, base station height, receiver height, distance and various environments have been considered in the analysis.

## **TABLE OF CONTENTS**

<b>Chapter No</b>	<b>Name of Chapter</b>	<b>Page No.</b>
<b>1.</b>	Introduction	7
<b>2.</b>	Literature Review	11
<b>3.</b>	Path Loss Model	13
<b>4.</b>	Simulation and Parameters	19
<b>5.</b>	Result	22
<b>6.</b>	Conclusion	38
<b>References</b>		40
<b>Appendixes</b>		42

# **CHAPTER 1**

## **INTRODUCTION**

Path loss is the decrease in power density or attenuation of an electromagnetic wave as it transmits through space. Path loss is a major factor in the analysis and design of the link budget of a telecommunication system. Path loss used in wireless communications a signal propagation. Path loss may be due to many things, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption. Path loss is also influenced by environment contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the space between the transmitter and the receiver, and the height and position of antennas.

Path loss can be denoted by the path loss exponent, whose value is normally in the range of 2 to 4 (where 2 is for propagation in free space, 4 is for relatively loss environments and for the case of full specular reflection from the earth surface called flat earth model). In some states, such as buildings, stadiums and other indoor states, the path loss exponent can reach values in the range of 4 to 6. On the other hand, a channel may act as a waveguide, resulting in a path loss exponent less than 2. Path loss is usually expressed in dB

In its simplest form, the path loss can be calculated by using this formula which is:

$$L=10n\log_{10}(d+C) \text{ ----- (1)}$$

Where

L is the path loss in decibel, n is the path loss exponent, d is the distance between the transmitter and the receiver, usually measured in meter. C is a constant which accounts for system losses.

### **OKUMURA MODEL:**

Okumura's model is one of the most broadly used models for signal prediction in urban areas. This model is valid for frequencies in the range 150–1920 MHz and distances of 1–100 km. It can be used for base-station antenna heights ranging from 30–1000 m. The Okumura model is a Radio propagation model that was built using the data collected in the city of Tokyo, Japan. The model is ideal for using in cities with many urban buildings but not many tall blocking structures. The model functioned as a base for the Hata Model.

Okumura model was founded into three modes. The one for urban, other for suburban and open areas. The model for urban areas was built first and used as the base for others.



The frequency for this model given below:

Frequency = 150–1920 MHz

Mobile station antenna height: between 1 m and 3 m

Base station antenna height: between 30 m and 1000 m

Link distance: between 1 km and 100 km

The Okumura model is formally expressed as:

$$L_m (dB) = L_F (d) + A_{mu} (f, d) - G (hr) - G (ht) - G_{AREA} \text{-----} (2)$$

Where;  $L_m$  = (i.e., median) of path loss

$L_F (d)$  = free space propagation path loss.

$A_{mu}(f, d)$  = median attenuation relative to free space

$G(h_b)$  = base station antenna height gain factor

$G(h_m)$  = mobile antenna height gain factor

$G(h_b) = 20 \log (h_b/200)$   $1000m > h_b > 30m$

$G(h_m) = 10 \log (h_m/3)$   $h_m \leq 3m$

$G(h_m) = 20 \log (h_m/3)$   $10m > h_m > 3m$

$G_{AREA}$ : gain due to type of environment given in suburban, urban or open areas Correction factors like terrain related parameters can be added using a graphical form to allow for street orientation as well as transmission in suburban and open areas and over irregular terrain. Irregular terrain is divided into rolling hilly terrain, isolated mountain, general sloping terrain and mixed land-sea path. The terrain related parameters that must be evaluated to determine the various corrections factors.

### **COST 231 Walfisch- Ikegami Model:**

COST 231 Hata model is an empirical model used for calculating path loss in cellular mobile system. This model is an extension of the Okumura-Hata model designed to cover frequency ranges from 1700Mz to 2300MHz with receiving antenna heights up to 10m and transmitting antenna heights of 30m-200m.COST 231 Hata model contains correction factors for urban, suburban, and rural areas. The equation for COST 231 Hata path loss model is conveyed as:

$$L_{COST231Hata} = 46.3 + 33.9 \log_{10}(fc) - 13.82 \log_{10}(ht) - a(hm) + [44.9 - .55 \log_{10}(ht)] \log_{10}(d) + C_m \text{.....} (3)$$

where,  $d$  is the link distance in Kilometers,  $f_c$  is the frequency in MHz,  $h_t$  is the effective height of the transmitting antenna in meters,  $h_r$  is the effective height of the receiving antenna in meters,  $C_m$  is the correction factor and is defined 0dB for rural or suburban and 3dB for urban area.

For rural or suburban area,

Correction factor for receiver antenna height,

$$a(h_m) = (1.1 \log_{10} f_c - 0.7) - (1.5 \log_{10} f_c - 0.8) \dots \dots (4)$$

For Urban,

$$a(h_m) = 3.2 \log_{10} (11.75 h_m)^2 - 4.79 \dots \dots (5)$$

Parameters:

Carrier Frequency: 1.5 GHz to 2 GHz

Base Antenna Height: 30 m to 300 m

Mobile Antenna Height: 1m to 10 m & Distance: 1 km to 20 km.

# **CHAPTER 2**

## **Literature Review**

In [1], the authors have compared three prominent channel models which would be used in LTE. They have compared between Stanford University Interim (SUI) models, Okumura model, Hata COST 231 model, COST Walfisch-Ikegami & Ericsson 9999 model.

In [2], the authors investigate different empirical propagation models for Long Term Evolution - Advanced (LTE-A) in the 2GHz band.

In [3], the author analyzed about the empirically based path loss channel model differences. It applies to distances and base antenna heights not well-covered by existing models. The characterization used is a linear curve fitting the decibel path loss to the decibel-distance, with a Gaussian random variation about that curve due to shadow fading. The resulting path loss model applies to base antenna heights from 10 to 80 m, base-to-terminal distances from 0.1 to 8 km, and three distinct terrain categories

In [4], the paper presents results of a measurement campaign carried out to examine applicability of the Okumura-Hata model in our region in various VHF/UHF frequency bands. It provided good approximation in the urban areas; the Okumura-Hata model gave significant errors in rural areas. Therefore paper describes an advance which allows changes to the Okumura-Hata model through statistical examination of the measurement results with application of the least squares method.

In [5], Radio propagation is essential for emerging technologies with appropriate design, deployment and management strategies for any wireless network. It is heavily site specific and can vary significantly depending on terrain, frequency of operation, velocity of mobile terminal, interface sources and other dynamic factor in these two channel model.

Similar works have been done in [5-12].

# CHAPTER 3

## PATH LOSS MODEL

The simplest channel is the free space line of sight channel with no objects between the receiver and the transmitter or around the path between them. In this simple case, the transmitted signal attenuates since the energy is spread spherically around the transmitting antenna. For this line of sight (LOS) channel, the received power is given by:

$$P_r = P_t \left[ \frac{\sqrt{G_1 \lambda}}{4\pi d} \right]^2 \text{----- (6)}$$

Here,  $P_t$  is the transmitted power,  
 $G_1$  is the product of the transmit and receive antenna field radiation patterns,  
 $\lambda$  is the wavelength, and  $d$  is the distance.

Theoretically, the power falls off in proportion to the square of the distance. In practice, the power falls off more quickly, typically 3rd or 4th power of distance. The most appropriate path loss model depends on the location of the receiving antenna. For the example below at:

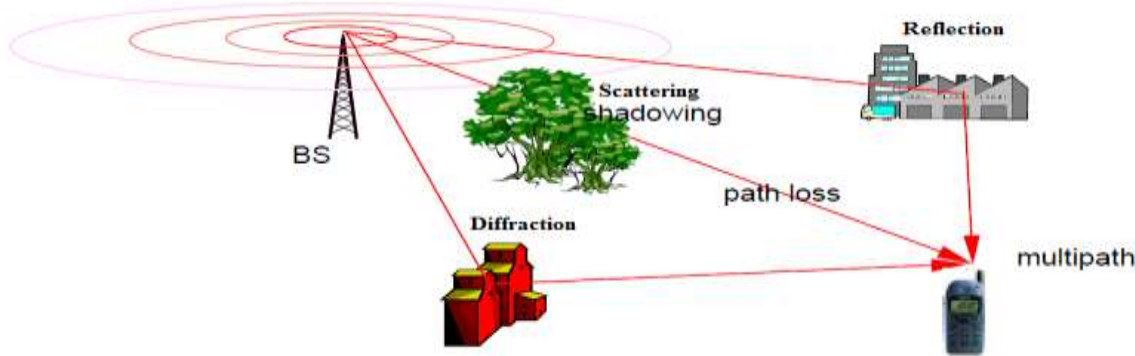


Fig: Path loss

Free space loss is likely to give an accurate estimate of path loss. A strong line-of-sight is present, but ground reflections can significantly influence path loss. The plane earth loss model appears appropriate. Plane earth loss needs to be corrected for significant diffraction losses, caused by trees cutting into the direct line of sight. A simple diffraction model is likely to give an accurate estimate

of path loss. Loss prediction fairly difficult and unreliable since multiple diffraction is present.

Path loss for different environment:

Environment	Path Loss Exponent (n)
Free Space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
Inside a building – Line of Sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in Factory	2 to 3

### Okumura model:

The Okumura model for urban areas is a Radio propagation model that was built using the data collected in the city of Tokyo, Japan. This model is applicable for frequencies in the range of 150 MHz to 1920 MHz and distances of 1 km to 100 km. It can be used for the base stations antenna heights ranging from 30 m to 1000 m. To determine path loss using Okumara’s model, the free space path loss between the points of interest is first determined and then the value of  $A_{mu}(f, d)$  is added to it along with correction factors according to the type of terrain. The model can be expressed as:

$$L_{50}(dB) = L_F + A_{mu}(f, d) - G(h_{te}) - G(h_{re}) - G_{AREA} \text{-----} (7)$$

Where,

$L_{50}$  is the 50th percentile path loss in dB

$L_F$  is the free space propagation loss in dB

$A_{mu}(f, d)$  is median attenuation in dB

$G(h_{te})$  is the base station antenna height gain factor.

$G(h_{re})$  is the mobile antenna height gain factor.

$G_{AREA}$  is the gain due to the type of environment moving from urban to suburban or open area.

$$G(h_{te}) = 20 \log \left( \frac{h_{te}}{200} \right); 1000m > h_{te} > 30m$$

$$G(h_{re}) = 10 \log \left( \frac{h_{re}}{3} \right); h_{re} \leq 3m$$

$$G(h_{re}) = 20 \log \left( \frac{h_{re}}{3} \right); 10m > h_{re} > 3m$$

3 types of prediction area Okumura-Hata model:

- Open area: open space, no tall trees or building in path.
- Suburban area: Village Highway scattered with trees and house some obstacles near the mobile but not very congested.
- Urban area: Built up city or large town with large building and houses Village with close houses and tall.
- Okumura takes urban areas as a reference and applies correction factors:

Urban areas:  $L_{dB} = A + B \log_{10}R - E$ ----- (8)

Suburban areas:  $L_{dB} = A + B \log_{10}R - C$ ----- (9)

Open areas:  $L_{dB} = A + B \log_{10}R - D$ ----- (10)

Where,

$$A = 69.55 + 26.16 \log_{10}f_c - 13.82 \log_{10}h_b$$

$$B = 44.9 - 6.55 \log_{10}h_b$$

$$C = 2 (\log_{10} (f_c / 28))^2 + 5.4$$

$$D = 4.78 (\log_{10}f_c)^2 + 18.33 \log_{10}f_c + 40.94$$

$$E = 3.2 (\log_{10} (11.7554h_m))^2 - 4.97 \quad \text{for large cities, } f_c \geq 300\text{MHz}$$

$$E = 8.29 (\log_{10} (1.54h_m))^2 - 1.1 \quad \text{for large cities, } f_c < 300\text{MHz}$$

$$E = (1.1 \log_{10}f_c - 0.7)h_m - (1.56 \log_{10}f_c - 0.8) \quad \text{for medium to small cities}$$

**COST 231 model:**

This model is a combination of experimental and deterministic models for approximating the path loss in an urban area over the frequency range of 800 MHz to 2000 MHz. The model is used primarily in Europe for the GSM 1800 system.

$$L_{50} = L_f + L_{rts} + L_{ms} \text{ dB} \text{----- (11)}$$



Where:

$L_f$ =Free space loss (dB)

$L_{rts}$  = roof top to street diffraction and scatter loss (dB)

$L_{ms}$  = multiscreen loss (dB)

Free space loss is given as:

$$L_f = 32.4 + 20 \log d + 20 \log f_c \text{ dB}$$

The roof top street diffraction and scatter loss is given a:

$$L_{rts} = -16.9 - 10 \log W + 10 \log f_c + 20 \log \Delta h_m + L_0 \text{ dB}$$

Where:

W= Street width (m)

$$\Delta h_m = h_r - h_m$$

$$L_0 = -10 - .354\Phi \text{ dB} \quad 0 \leq \Phi \leq 35^\circ$$

$$L_0 = 2.5 + 0.075(\Phi - 35) \text{ dB} \quad 35^\circ \leq \Phi \leq 55^\circ$$

$$L_0 = 4 - .114(\Phi - 55) \text{ dB} \quad 55^\circ \leq \Phi \leq 90^\circ$$

Where:

$\Phi$  = *incident angle* Relative to street the multiscreen (multi-scatter) loss is given as:

$$L_{ms} = L_{bsh} + K_a + K_d \log d + K_f \log f_c - 9 \log b \text{----- (12)}$$

Where

b=distance between building along radio path (m)

d=separation between transmitter and receiver (km)

$$L_{bsh} = -18 \log(11 + \Delta h_b) \quad h_b \geq h_r$$

$$L_{bsh} = 0 \quad h_b < h_r$$

$$\Delta h_b = h_b - h_r, h_r = \text{average buildings height(m)}$$

$$k_a = 54 \quad h_b > h_r$$

$$k_a = 54 - 0.8h_b \quad d \geq 500\text{m}; h_b \leq h_r$$

$$k_a = 54 - 0.8\Delta h_b \left( \frac{d}{500} \right) \quad d < 500\text{m}; h_b \leq h_r$$

Both  $L_{bsh}$  and  $k_d$  increase path loss with lower base station antenna height.

$$k_d = 18 \quad h_b < h_r$$

$$k_d = 18 - \frac{15\Delta h_b}{\Delta h_m} h_b \geq h_r$$

$$k_f = 4 + 0.7 \left( \frac{f_c}{925} - 1 \right) \text{ for mid size city and suburban area with moderate tree density}$$

$$k_f = 4 + 1.5 \left( \frac{f_c}{925} - 1 \right) \text{ for metropolitan area}$$

The range of parameters for which the COST 231 model is valid is:

$$800 < f_c < 2000 \text{ MHz}$$

$$4 \leq h_b \leq 50 \text{ m}$$

$$1 \leq h_m \leq 3 \text{ m}$$

$$0.02 \leq d \leq 5 \text{ km}$$

The following default values may be used in the model:

$$b = 20\text{-}50 \text{ m}$$

$$W = b/2$$

$$\phi = 90^\circ$$

Roof = 3m for pitched roof and 0m for flat roof,

And  $h_r = 3(\text{number of floor}) + \text{roof}$

This model is restricted to the following range of parameters:

Carrier Frequency	1.5 GHz to 2 GHz
Base Antenna Height	30 m to 300 m
Mobile Antenna Height	1m to 10 m
Distance d	1 km to 20 km

COST 321-Hata model is designed for large and small macro-cells, i.e., base station antenna heights above rooftop levels adjacent to base station.

# **CHAPTER 4**

## **SIMULATIONS AND PARAMETERS**

All of our results have been found after done the simulations in MATLAB R2016a software.

MATLAB is a high-performance language for technical calculating. It integrates calculation, visualization, and programming in an easy-to-use situation where problems and solutions are expressed in familiar mathematical notation. Typical uses include:

- ❖ Math and computation
- ❖ Algorithm development
- ❖ Modeling, simulation, and prototyping
- ❖ Data analysis, exploration, and visualization
- ❖ Scientific and engineering graphics
- ❖ Application development, including Graphical User Interface building



MATLAB is an communicating system whose basic data component is an array that does not require dimensioning. This permits you to solve many technical calculating problems, particularly those with matrix and vector designs, in a fraction of the time it would take to write a program in a scalar no communicating language such as C or FORTRAN.

MATLAB use for attitudes matrix laboratory. MATLAB was initially written to provide easy access to matrix software industrialized by the LINPACK and EISPACK projects, which composed characterize the state-of-the-art in software for matrix computation. MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity exploration, development, and analysis. MATLAB features a family of application-specific keys called toolboxes. Very important to most users of MATLAB, toolboxes allow you to *study* and *apply* specialized technology. Toolboxes are comprehensive collections of MATLAB functions (M-files) that extend the MATLAB environment to solve specific classes of problems. Areas in which toolboxes are accessible include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation, and many others.

The following parameters have been in our simulation:

**Table 2: Simulation Parameters**

<b>Parameter</b>	<b>Value</b>
Frequency	1500 MHz, 1800 MHz, 2000 MHz
transmitter height	50m, 80m, 100m, 150m, 200m
receiver height (from ground)	2m, 5m, 10m
Distance between sender and receiver	1-20 km

# CHAPTER 5

## RESULTS

This section deals with the result obtained after the simulations.

In Fig. 1, the Path-loss vs. distance for 1500 MHz has been displayed. Here, the transmitter height has been considered as 50 meter while received height is 2 meter. In this figure, the Hata model shows the lower path loss than the Cost231 model. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the performance can be differentiated. If we consider the value of distance,  $d= 10$  km then the path loss by Hata model is around 163 dB (for both medium sized city and metropolitan city) while by Cost model is around 204 dB medium sized city and 210 dB for metropolitan city.

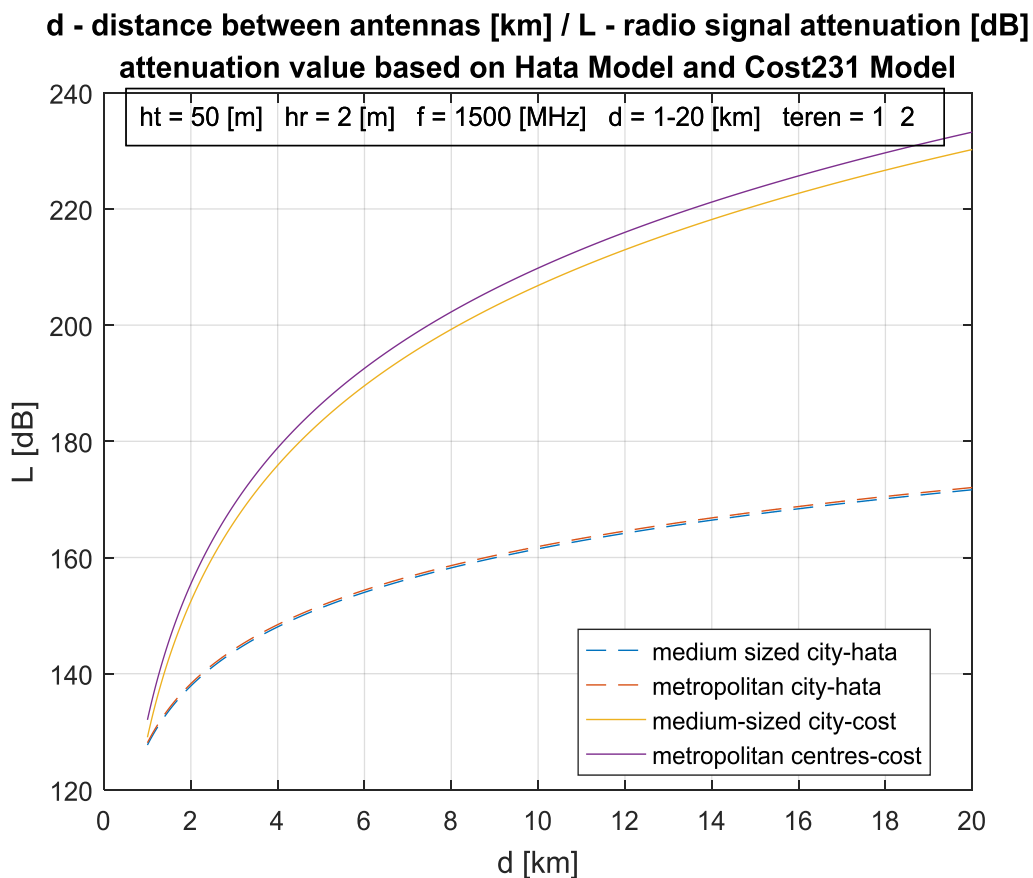


Fig. 1 Path-loss vs distance for 1500 MHz, transmitter height=50m and receiver height=2m

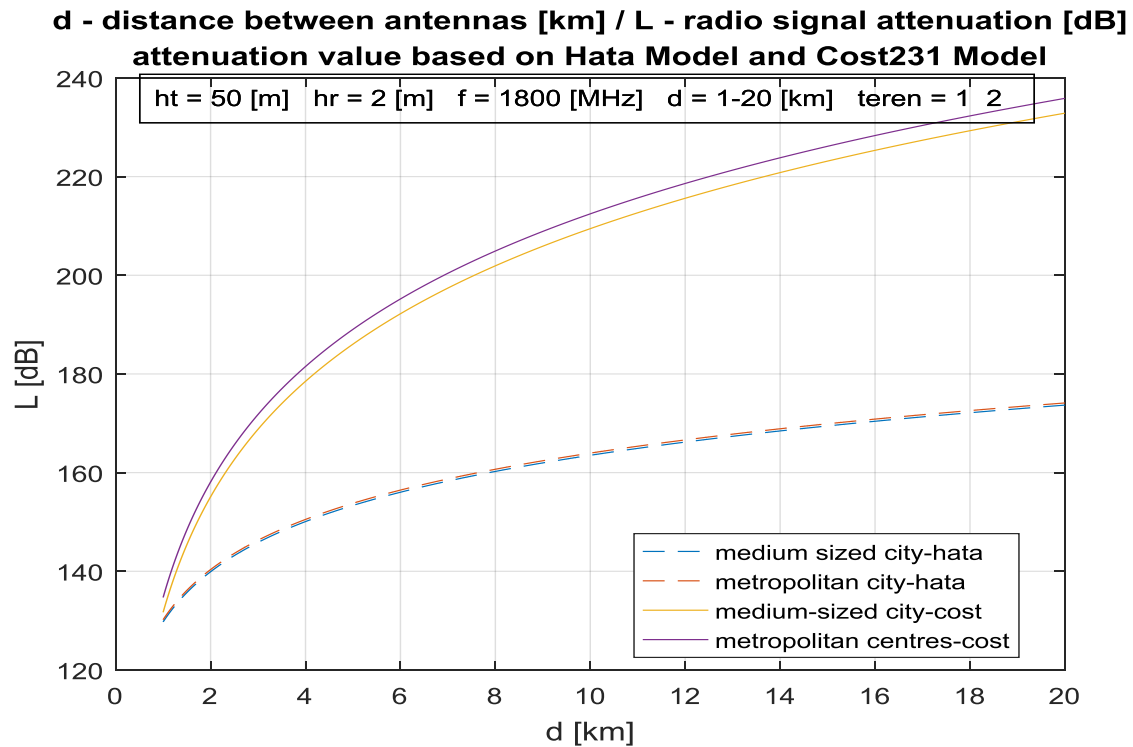


Fig. 2 Path-loss vs distance for 1800 MHz, transmitter height=50m and receiver height=2m

In Fig. 2, the Path-loss vs. distance for 1800 MHz has been displayed. Here, the transmitter height has been considered as 50 meter while received height is 2 meter. In this figure, the Hata model shows the lower path loss than the Cost231 model. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the performance can be differentiated.



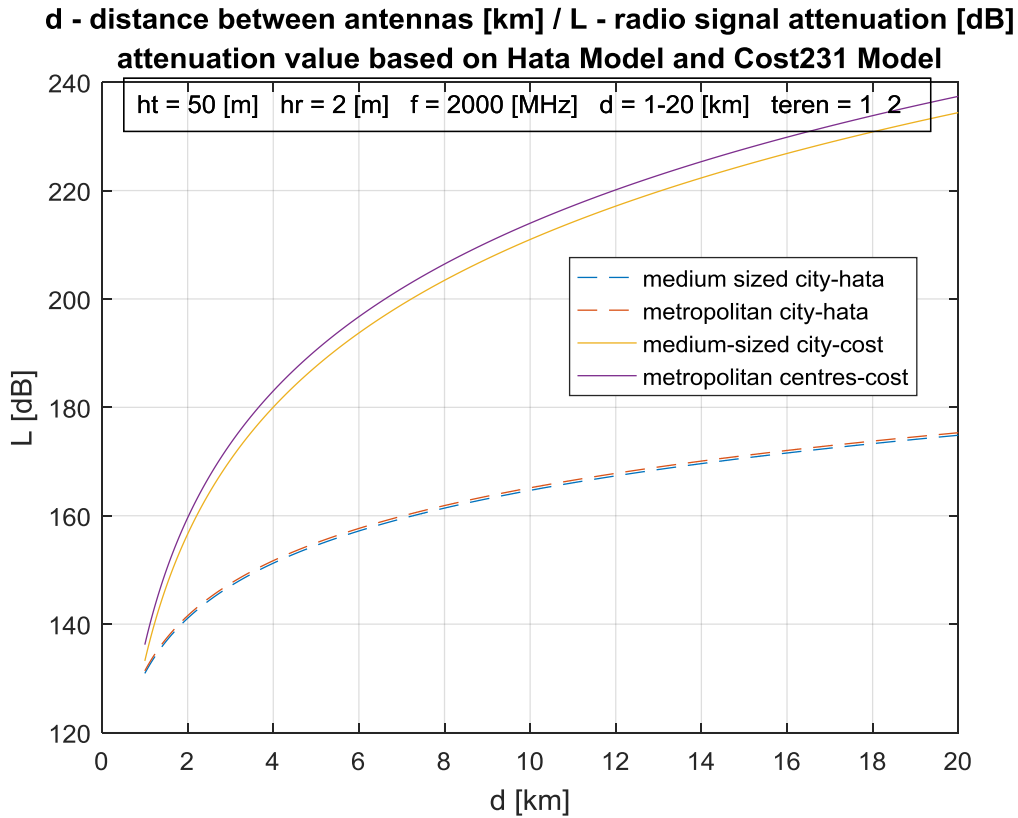


Fig. 3 Path-loss vs distance for 2000 MHz, transmitter height=50m and receiver height=2m

Similar results have been found in In Fig. 3 though frequency used here is 2000 MHz. So, changing the frequency would not affect the path loss by both the models. In this fig, the Path-loss vs. distance for 2000MHz has been displayed. Here, the transmitter height has been considered as 50 meter while received height is 2 meter.

In Fig. 3, the Path-loss vs distance for 2000 MHz has been displayed. Almost similar results to Fig.2 have been found in Fig. 3. Here Hata model also shows the better results..

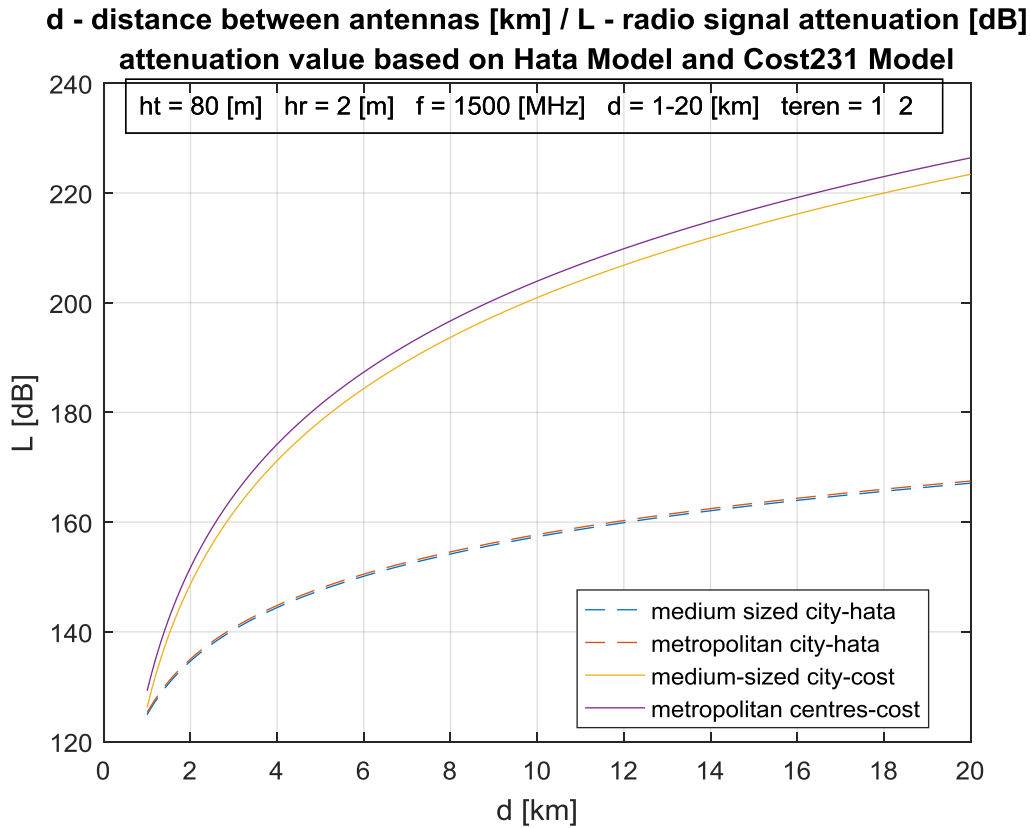


Fig. 4 Path-loss vs distance for 1500 MHz, transmitter height=80m and receiver height=2m

In Fig. 4, the Path-loss vs. distance for 1500 MHz has been displayed. Here, the transmitter height has been considered as 80 meter while received height is 2 meter. In this figure, the Hata model shows the lower path loss than the Cost231 model. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the act can be differentiated.

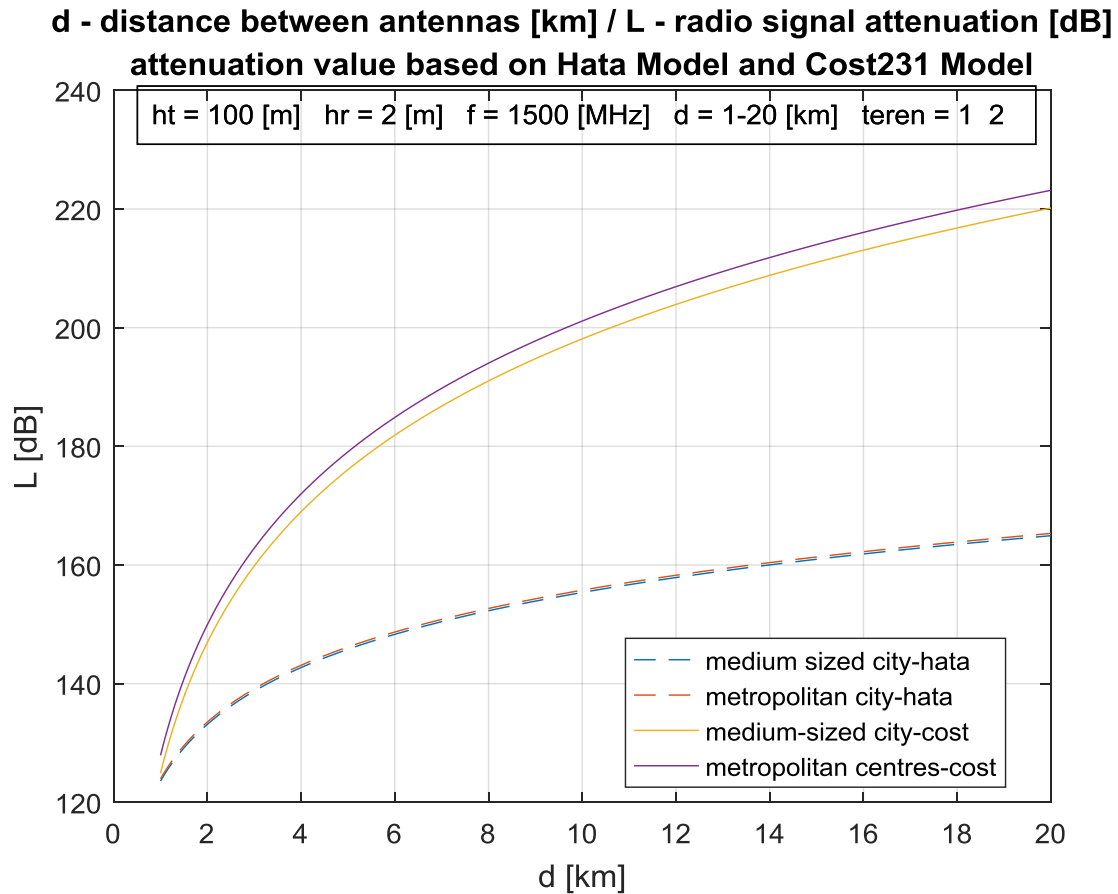


Fig. 5 Path-loss vs distance for 1500 MHz, transmitter height=100m and receiver height=2m

In Fig. 5, the Path-loss vs. distance for 1500 MHz has been displayed. Here, the transmitter height has been considered as 100 meter while received height is 2 meter. In this figure, the Hata model shows the lower path loss than the Cost231 model. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the act can be differentiated.

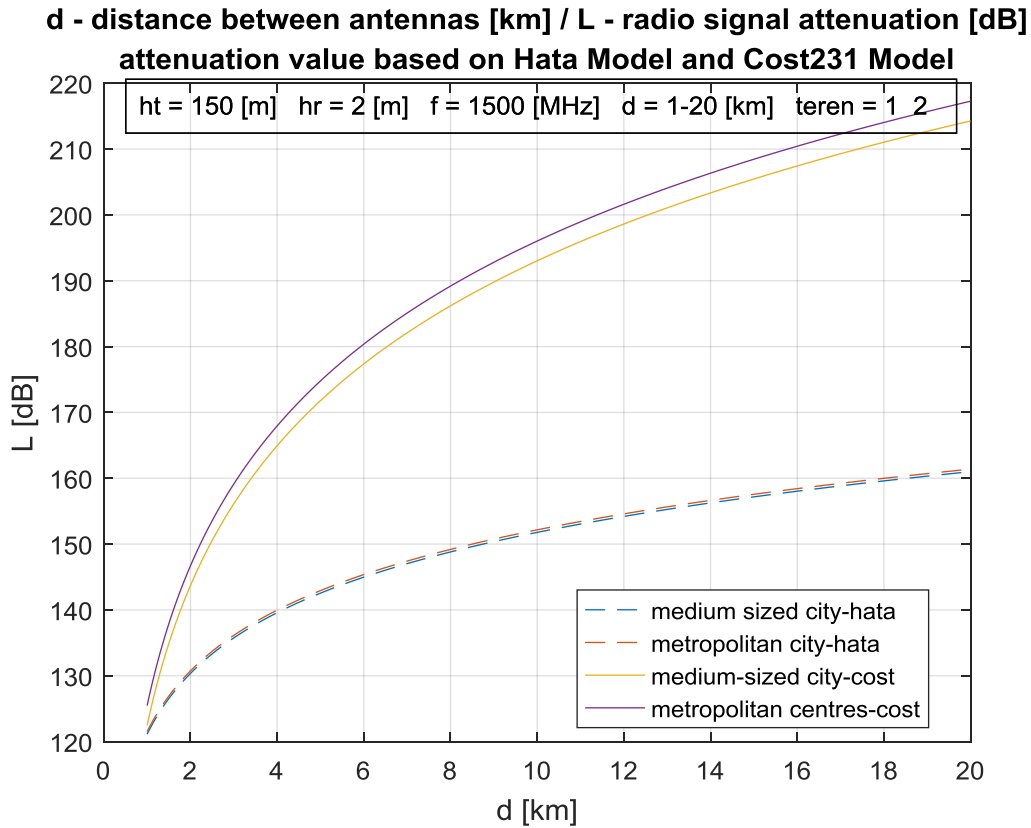


Fig. 6 Path-loss vs distance for 1500 MHz, transmitter height=150m and receiver height=2m

In Fig. 6, the Path-loss vs. distance for 1500 MHz has been displayed. Here, the transmitter height has been considered as 150 meter while received height is 2 meter. Similarly in fig 5; the Hata model shows the lower path loss than the Cost231 model. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the performance can be differentiated.

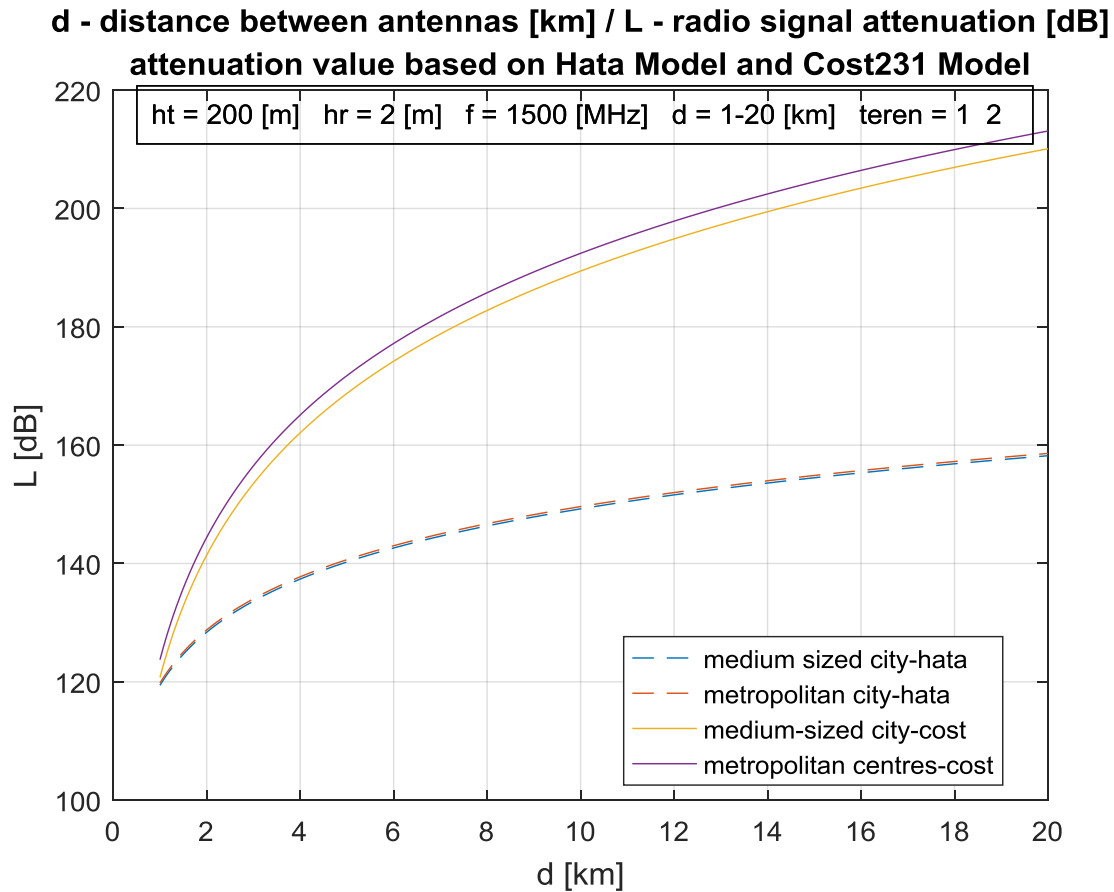


Fig. 7 Path-loss vs distance for 1500 MHz, transmitter height=80m and receiver height=2m

Now, we have changed the parameter for the simulation. Here we have considered the transmitter height as 80 meter. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the performances almost the same for both the cases. From this Fig.5 we can conclude that increasing the transmitter height from 50 meter to 80 meter will lead the path loss in decreasing.

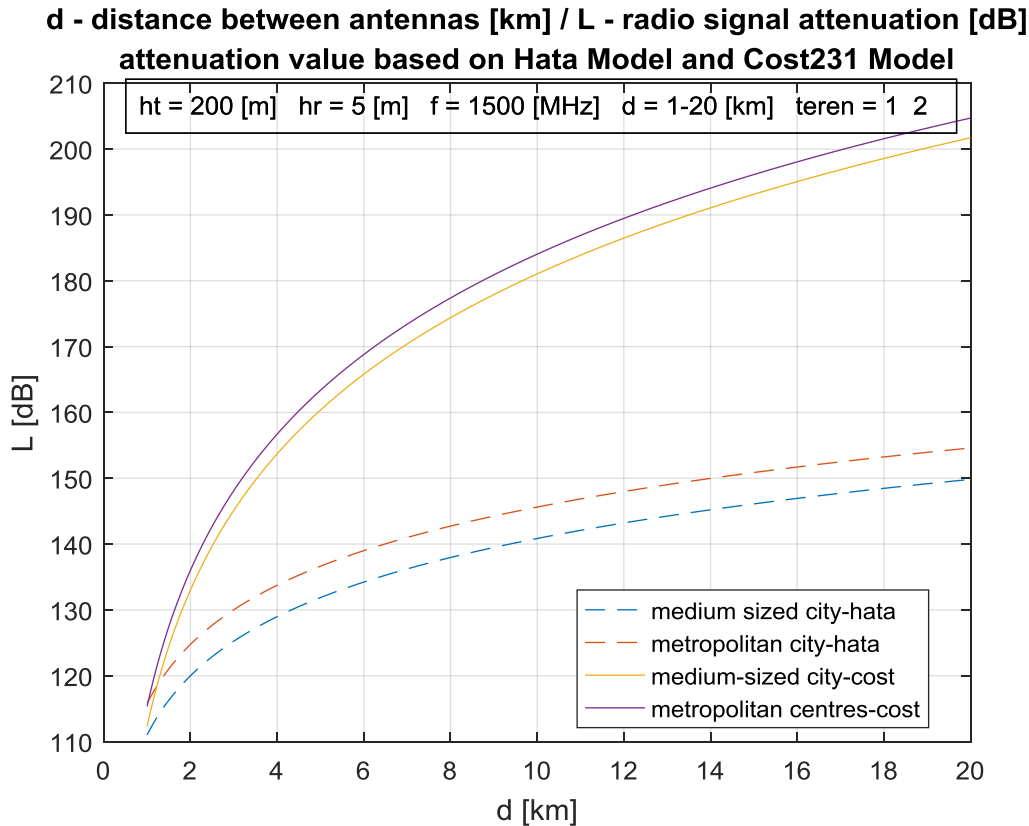


Fig.8 Path-loss vs distance for 1500 MHz, transmitter height=200m and receiver height=5m

In Fig. 8, the Path-loss vs distance for 1500 MHz has been displayed. Here, the transmitter height has been considered as 200 meter while received height is 5meter. In this figure, the Hata model shows the lower path loss than the Cost231 model. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the act can be differentiated. If we consider the value of distance,  $d = 10$  km then the path loss by Hata model is around 153 dB (for both medium sized city and metropolitan city) while by Cost model is around 204 dB medium sized city and 210 dB for metropolitan city.

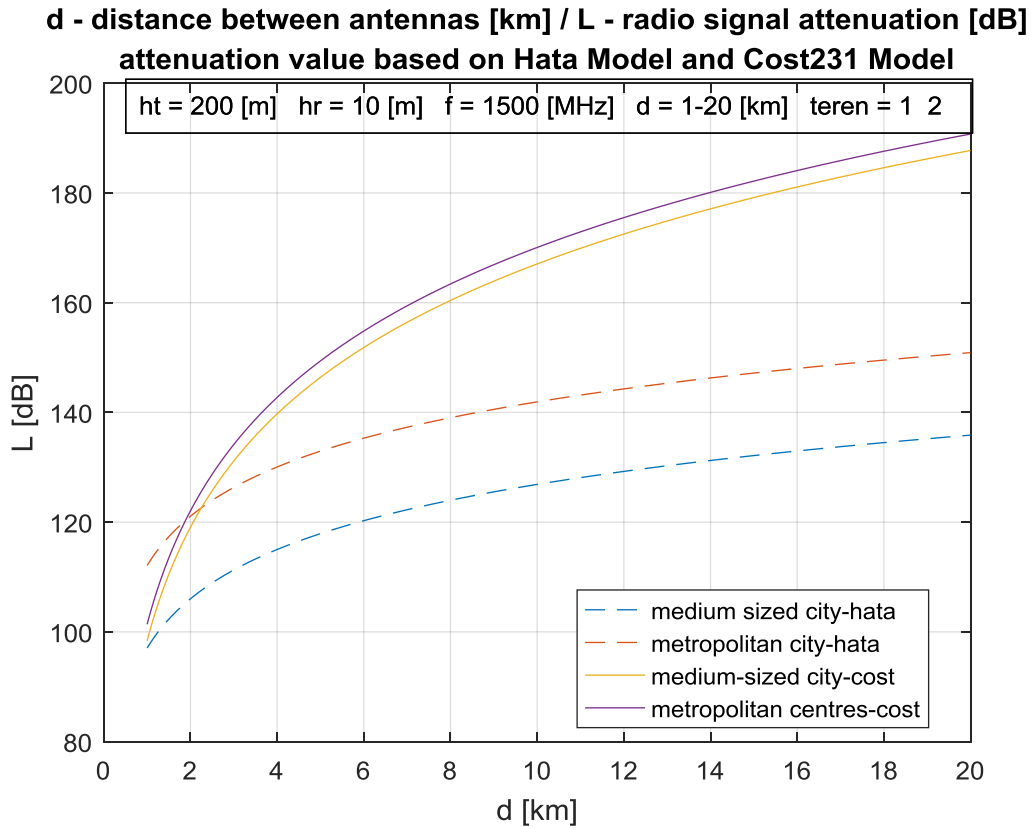


Fig. 9 Path-loss vs distance for 1500 MHz, transmitter height=100m and receiver height=2m

From Fig.9, it is observable that the increasing in transmitter height from 80 meter to 100 meter will not lead the significant decrease in path loss compare to the previous case. But if we increase the transmitter height as 150 meter than the path loss found significantly lower than the case of 100 meter or 80 meter cases (Fig. 8). But still Hata model performs the better. Same observation can be found in Fig. 10.

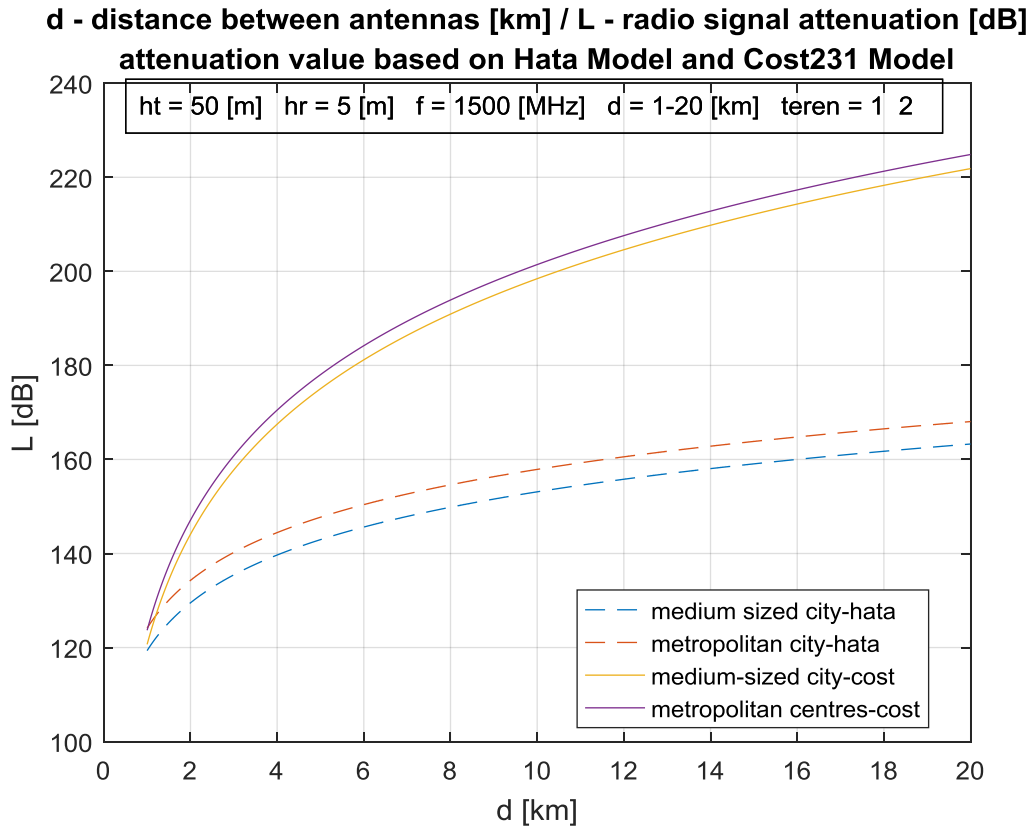


Fig. 10 Path-loss vs distance for 1500 MHz, transmitter height=150m and receiver height=2m

In this figure, the Hata model shows the lower path loss than the Cost231 model. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the performance can be differentiated.



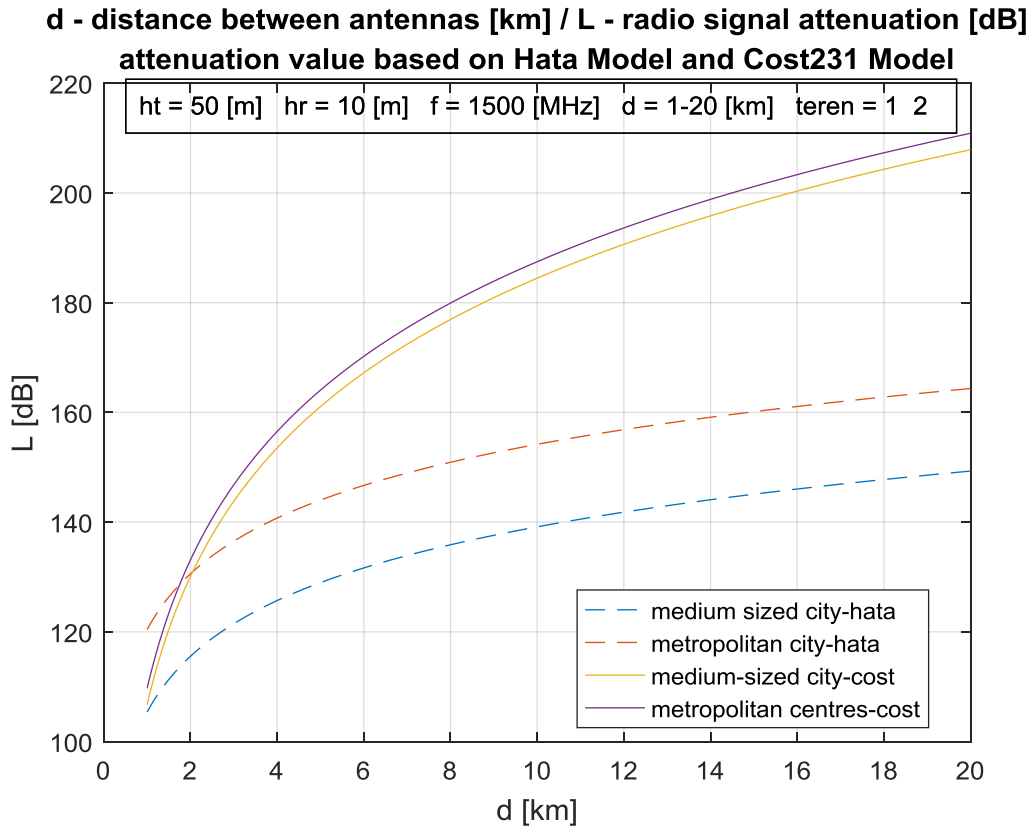


Fig. 11 Path-loss vs distance for 1500 MHz, transmitter height=200m and receiver height=2m

In Fig. 11, path loss analysis has been done for 1500 MHz scenario with transmitter height=200 meter and receiver height=5 meter. It is found that the results of Hata model for both the medium sized and metropolitan city is no longer identical. There is a difference between these two terrains. But in the case of Cost231 model the result are quite similar for both the cases. In this figure, the Hata model shows the lower path loss than the Cost231 model. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the performance can be differentiated.

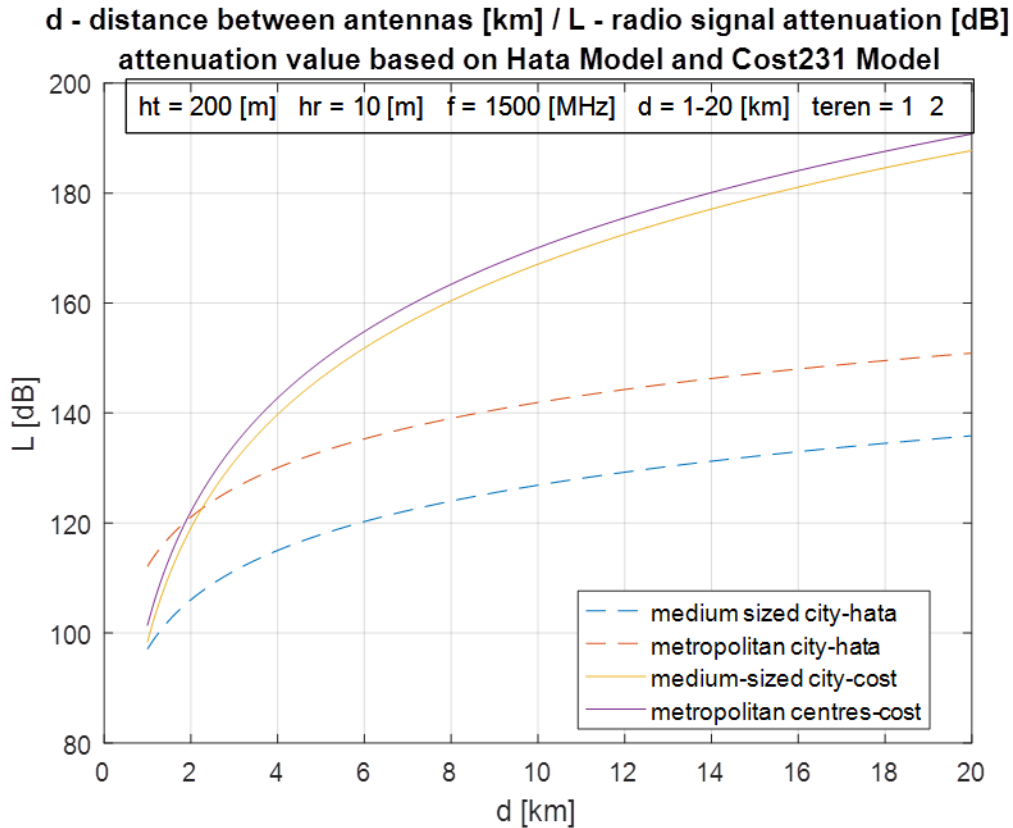


Fig. 12 Path-loss vs distance for 1500 MHz, transmitter height=200m and receiver height=5m

In Fig. 12, path loss analysis has been done for 1500 MHz scenario with transmitter height=200 meter and receiver height=5 meter. It is found that the results of Hata model for both the medium sized and metropolitan city is no longer identical. There is a difference between these two terrains. But in the case of Cost231 model the result are quite similar for both the cases.

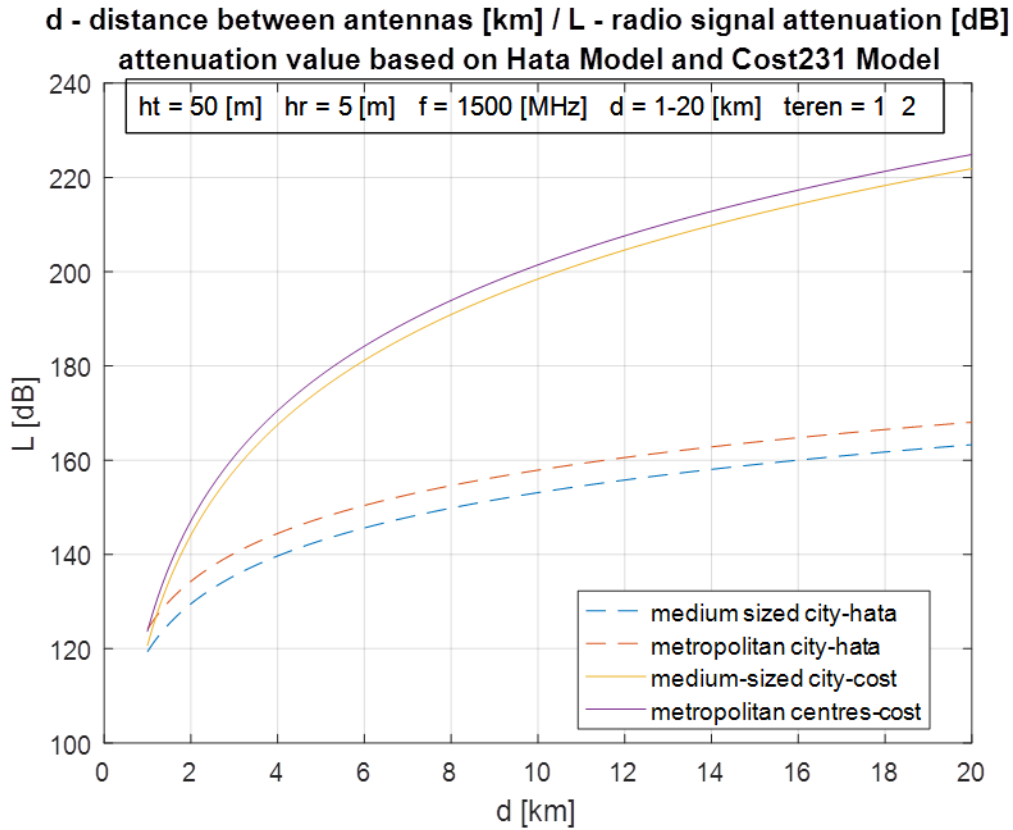


Fig. 13 Path-loss vs distance for 1500 MHz, transmitter height=200m and receiver height=10m

Now if we increase the height of the receiver antenna the path loss difference between the medium sized and metropolitan city of Hata models are also increased but the overall path loss is decreasing. The phenomena have been found in Fig. 14.

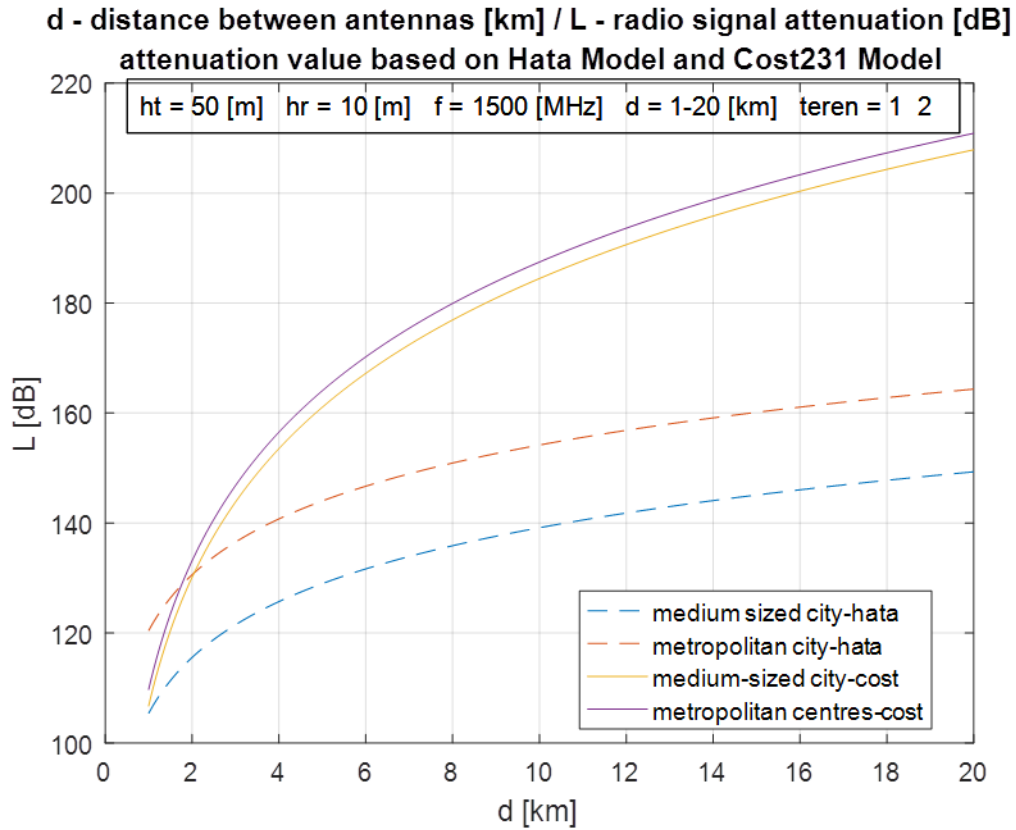


Fig. 14 Path-loss vs distance for 1500 MHz, transmitter height=50m and receiver height=5m

In Fig. 14, the Path-loss vs distance for 1500 MHz has been displayed. Here, the transmitter height has been considered as 50 meter while received height is 5 meter. In this figure, the Hata model shows the lower path loss than the Cost231 model. Hata model for both medium sized city and metropolitan city give the identical results but in case of Cost model the performance can be differentiated.

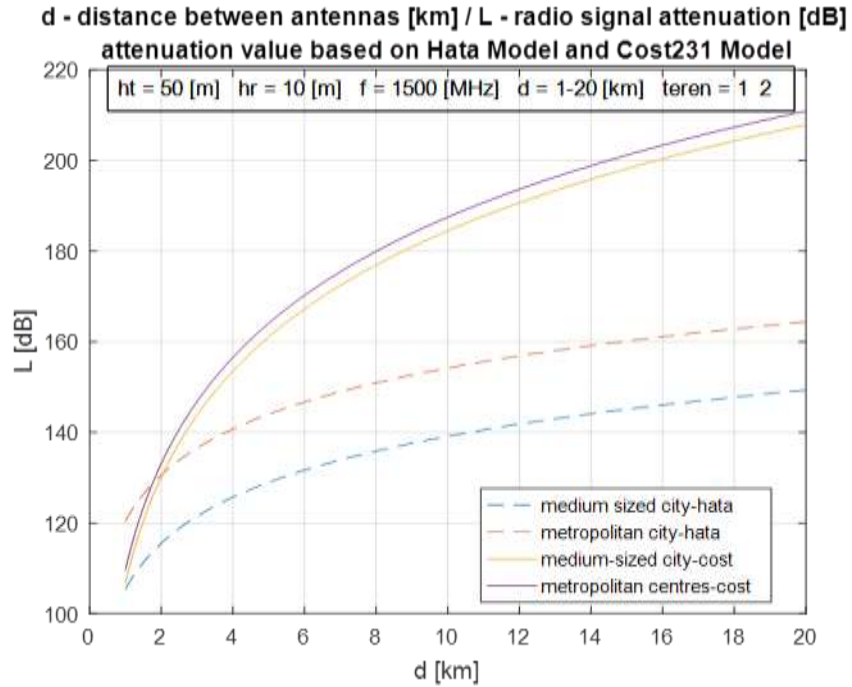


Fig. 15 Path-loss vs distance for 1500 MHz, transmitter height=50m and receiver height=10m. Compare to Fig. 13 and Fig. 14, it has been found that increasing the receiver height increases the performance (i.e. less path loss). It's also found that the path loss difference between the medium sized and metropolitan city of Hata models is increasing due to the increase of the receiver height but little impact of the transmitter height.

# CHAPTER 6

## CONCLUSION

In this paper, the path loss performances of Hata model and Cost231 model have been analyzed for different scenarios. In all the cases, Hata model's performances are found better than the Cost 231 model. It's also found that increasing the frequency is not changing the path loss value remarkably. But, if we increase the transmitter height than the path loss is decreasing in all the cases. Again, if we increase the receiver height the performance of both the model is also increased. The performances of Hata model for medium sized city and metropolitan city almost identical for any frequency change and transmitter height change, but it creates difference when the receiver height is changed. Similar change for Cost231 case has been found when we change the frequency, but it's not impacted when change the transmitter or receiver height. In a conclusion, for the better performance, Hata model should be used with proper transmitter and receiver height consideration.

# References

- [1] Shabbir, Noman, Muhammad T. Sadiq, HasnainKashif, and RizwanUllah. "Comparison of radio propagation models for long term evolution (Lte) network." arXiv preprint arXiv: 1110.1519 (2011).
- [2] Ahmad, Yassir A., Walid A. Hassan, and Tharek Abdul Rahman. "Studying different propagation models for LTE-A system." In Computer and Communication Engineering (ICCCE), 2012 International Conference on, pp. 848-853. IEEE, 2012.
- [3] Erceg, Vinko, Larry J. Greenstein, Sony Y. Tjandra, Seth R. Parkoff, Ajay Gupta, Boris Kulic, Arthur A. Julius, and Renee Bianchi. "An empirically based path loss model for wireless channels in suburban environments." IEEE Journal on selected areas in communications 17, no.7 (1999):1205-1211.
- [4] Roslee, Mardeni Bin, and KokFoong Kwan. "Optimization of Hata propagation prediction model in suburban area in Malaysia." Progress In Electromagnetics Research C 13 (2010): 91-106.
- [5] Singh, Yuvraj. "Comparison of okumura, hata and cost-231 models on the basis of path loss and signal strength."International journal of computer applications 59, no. 11 (2012).
- [6] [Okumura1968] T. Okumura, E. Ohmore, and K. Fukuda, "Field strength and its variability in VHF and UHF land mobile service," Rev. Elec. Communes. Lab., pp. 825-73, September-October 1968.
- [7] [Hata1980] M. Hata, "Empirical formula for propagation loss for mobile radio services," IEEE Trans. Veh. Tech., pp. 317-25, August 1980. [COST231] European Cooperative in the Field of Science and Technical Research EURO-COST 231, "Urban transmission loss models for mobile radio in the 900- and 1,800 MHz bands
- [8] [Erceg1999] V. Erceg et al, "An empirically based path loss model for wireless channels in suburban environments," IEEE JSAC, vol. 17, no. 7, July 1999, pp. 1205-1211.
- [9] Dinesh Sharma, R.K.Singh, "The Effect of Path Loss on QoS at NPL" International Journal of Engineering Science and Technology Vol. 2(7), 2010, 3018-3023.
- [10]Jean-Paul M. G. Linmartz's, Wireless Communication, The Interactive Multimedia CD-ROM, Baltzer Science Publishers, P.O.Box 37208, 1030 AE Amsterdam, ISSN 1383 4231, Vol. 1 (1996), No.1



[11] Theodore.S.R., 2006, “Wireless Communications Principles and Practice”, Prentice-Hall, India.

[12] Walfisch, J., and Bertoni, H. L. “A Theoretical Model of UHF Propagation in Urban Environment.” *IEEE Transactions, Antennas & Propagation*, AP-36:1788– 1796, October 1988.

# Appendixes

*Matlab codes*

```
%  


---

  
%for the cost231  
  
function [hL50dB] = cost231hata(hBSef, hMS, f, d, area)  
%COST231Hata - function returns signal attenuation value based on  
%      COST231-Hata Model  
%  
% hL50dB = cost231hata(hBSef, hMS, f, d, area)  
%  
% hL50dB - radio signal attenuation [dB]  
%  
% hBSef - effective base station antenna height [m]  
%      30 <= hBS,ef <= 200 m  
% hMS - mobile station antenna height [m]  
%      1 <= hMS <= 10 m  
% f - frequency [MHz]  
%      1500 <= f <= 2000 MHz  
% d - distance between antennas [km]  
%      1 <= d <= 20 km  
% area - area type: {1, 2}  
%      1 - medium-sized city  2 - metropolitan centres  
  
n = 0;  
  
for i = (area)  
n = n + 1;  
if((min(f)>=1500)&&(max(f)<=2000))  
if((min(hBSef)>=30)&&(max(hBSef)<=200))  
if((min(hMS)>=1)&&(max(hMS)<=10))  
if((i==1)||(i==2))  
if((min(d)>=1)&&(max(d)<=20))  
ahMS = (1.1 * log10(f) - 0.7) * hMS - (1.56 * log10(f) - 0.8);  
if(i==1)
```

```

        C = 0;
end
if(i==2)
    C = 3;
end

    L50dB = 46.3 + 33.9 * log10(f) - 13.82 * log10(hBSef) - ahMS + (44.9 - 6.55 *
log10(hBSef)) * log(d) + C;
hL50dB(n,:) = L50dB;

else
disp('ERROR: required distance between antennas = 1 <= d <= 20 km');
end
else
disp('ERROR: required area type = 1 lub 2');
end
else
disp('ERROR: required mobile station antenna height = 1 <= hMS<= 10 m');
end
else
disp('ERROR: required effective base station antenna height = 30 <= hBS,ef<= 200 m');
end
else
disp('ERROR: required frequency = 1500 <= f <= 2000 MHz');
end
end
end

%_____

%_____

    function [hL50dB] = hata(hBSef, hMS, f, d, area)
%Hata - function returns signal attenuation value based on Hata Model
%
% hL50dB = hata(hBSef, hMS, f, d, area)
%
% hL50dB - radio signal attenuation [dB]

```

```

%
% hBSef - effective base station antenna height [m]
%  $30 \leq hBS,ef \leq 200$  m
% hMS - mobile station antenna height [m]
%  $1 \leq hMS \leq 10$  m
% f - frequency [MHz]
%  $150 \leq f \leq 1800$  MHz
% d - distance between antennas [km]
%  $1 \leq d \leq 20$  km
% area - area type: {1, 2, 3, 4}
% 1 - medium-sized city
% 2 - metropolitan city  $400 \leq f \leq 200$  MHz

n = 0;

for i = (area)
n = n + 1;
if((min(f)>=150)&&(max(f)<=2000))
if((min(hBSef)>=30)&&(max(hBSef)<=200))
if((min(hMS)>=1)&&(max(hMS)<=10))
if((i==1)||(i==2)||(i==3)||(i==4))
if((min(d)>=1)&&(max(d)<=20))

if((i==1)||(i==3)||(i==4))
ahMS = (1.1 * log10(f) - 0.7) * hMS - (1.56 * log10(f) - 0.8);
end

if(i==2)
if(max(f)<=200)
ahMS = 8.29 * (log10(1.54 * hMS))^2 - 1.1;
end

if(min(f)>=400)
ahMS = 3.2 * (log10(11.75 * hMS))^2 - 4.97;
end

if((min(f)>200)&&(max(f)<400))
disp('ERROR: required frequency for large city = 400 <= f <= 200 MHz');
return;
end

```

*end*

$L50dB = 69.55 + 26.16 * \log_{10}(f) - 13.82 * \log_{10}(hBSef) - ahMS + (44.9 - 6.55 * \log_{10}(hBSef)) * \log_{10}(d);$

*if(i==3)*

$L50dB = L50dB - 2 * (\log_{10}(f/28))^2 - 5.4;$

*end*

*if(i==4)*

$L50dB = L50dB - 4.78 * \log_{10}(f)^2 + 18.33 * \log_{10}(f) - 40.94;$

*end*

$hL50dB(n,:) = L50dB;$

*else*

$disp('ERROR: required distance between antennas = 1 <= d <= 20 km');$

*return;*

*end*

*else*

$disp('ERROR: required area type = 1 lub 2 lub 3 lub 4');$

*return;*

*end*

*else*

$disp('ERROR: required mobile station antenna height = 1 <= hMS <= 10 m');$

*return;*

*end*

*else*

$disp('ERROR: required effective base station antenna height = 30 <= hBS,ef <= 200 m');$

*return;*

*end*

*else*

$disp('ERROR: required frequency = 150 <= f <= 1800 MHz');$

*return;*

*end*

*end*

*end*

*%*

*% for f=1500 MHz,*

```

clear all;

% hBSef - effective base station antenna height [m]
% 30 <= hBS,ef <= 200 m
ht = 50; %[m]

% hMS - mobile station antenna height [m]
% 1 <= hMS <= 10 m
hr = 2; %[m]

% f - frequency [MHz]
% 1500 <= f <= 2000 MHz
f = 1500; %[MHz]

% d - distance between antennas [km]
% 1 <= d <= 20 km
from = 1; %[km]
to = 20; %[km]
precision = 0.01; %[km]
d = from:precision:to; %[km]

area = [1,2];

% hL50dB = hata(hBSef, hMS, f, d, area)
L = hata(ht, hr, f, d, area);
% hL50dB = cost231hata(hBSef, hMS, f, d, area)
L1 = cost231hata(ht, hr, f, d, area);

clf reset;
plot(d, L, '--');
desc = ['ht = ',num2str(ht),' [m] hr = ',num2str(hr),' [m] f = ',...
num2str(f),' [MHz] d = ',num2str(from),'-',num2str(to),' [km] teren = ', num2str(area)];
annotation('textbox',[0.15 0.7 0.2 0.2],'String',{desc},'FitBoxToText','on');

hold on

```

```

plot(d, L1, '-');
desc = ['ht = ',num2str(ht),' [m]  hr = ',num2str(hr),' [m]  f = ',...
num2str(f),' [MHz]  d = ',num2str(from),'-',num2str(to),' [km]  teren = ', num2str(area)];
annotation('textbox',[0.15 0.7 0.2 0.2],'String',{desc},'FitBoxToText','on');
grid on;
axis auto;
title({'d - distance between antennas [km] / L - radio signal attenuation [dB]';...
'attenuation value based on Hata Model and Cost231 Model'});
xlabel('d [km]');
ylabel('L [dB]');

legend('medium sized city-hata','metropolitan city-hata','medium-sized city-
cost','metropolitancentres-cost','location','Best');

%_____

```