SIMULATION OF MOBILE STATION ANTENNA HEIGHT FACTOR EFFECT AGAINST THE PATH LOSS IN A VARIETY OF MOBILE PROPAGATION MODELS

Martinus Mujur Rose [1]

[1)]*Electrical Engineering, Politeknik Negeri Sriwijaya, Palembang, Indonesia*
E-mail: mujurrose@yahoo.com

Abstract.. Learning and teaching the course of Mobile Communications Systems for several semester caught the attention of the author of this article to one thing, namely the inconsistency between the given propagation equation (such as Okumura-Hata) and the completely usage of all components in the equation, when doing the planning of cellular coverage or calculating the path loss.There is a component in the equation which is writtenbut sometimes does not used in the examples of problems solution. The component is the Mobile Station antenna height factor, symbolized by *a (hm)*, where *a* as a function of *hm* and *hm* itself is a mobile station antenna height. Then the question is whether the effect of Mobile Station antenna height factor to the path loss could be ignored? or when it should be including the factor of *a(hm)* and when it should not be including. Here, this problems is then verified through a method of simulation using Matlab. The result shows the *pathloss* of 2 compared models, where the 2 models were differensiated by using or does not using Mobile Station antenna height factor. The conclusion is, the very least value of pathloss difference between 2 compared models occurs when the Mobile Station antenna height is 1.5 meters. It means that when the assumption of Mobile Station antenna height is 1.5 meters, then it is not important to include *a(hm)* factor because its effect to the pathloss is very insignificant, where the different mean value is0,0024%.

Keywords**:** Path Loss ; mobile station ; antenna height ; simulation.

I. INTRODUCTION

Learning and teaching the course of Mobile Communications Systems for several semester caught the attention of the author of this article to one thing. The thing is that in several case, it looks like there is the inconsistency between the given propagation equation (such as Okumura-Hata) and the completely usage of all components in the equation, when doing the planning of cellular coverage or calculating the path loss.There is a component in the equation which is written but sometimes does not used in the examples of problems solution. The component is the Mobile Station antenna height factor, symbolized by *a (hm)*, where *a* as a function of *hm* and *hm* itself is a mobile station antenna height.Then the question is whether the effect of Mobile Station antenna height factor to the path loss could be ignored? or in other words, is the effect of *a(hm)* very insignificant?or when it should be including the factor of *a(hm)* and when it should not be including.This question has encouraged the authors conducted an experiment through software simulations using MATLAB.

II. LITERATURE REVIEW

A. *Okumura – Hata. Ref: [2], [1], [3],[4]*

The path loss of mobile propagation in Okumura-Hata Models is described as below:

$$P_L = A + B\log(d) + C \quad \ldots\ldots\ldots\ldots(1)$$

where$A$, B, and$C$are the factors depends on frequency and antenna height, namely:

$$A = 69.55 + 26.16\log(f_c) - 13.82\log(h_b) - a(h_m) \ldots (2)$$

$$B = 44.9 - 6.55\log(h_b) \ldots\ldots\ldots\ldots (3)$$

Where f_c in MHz, and d in Km(s). While $a(h_m)$ and C is depends on area classification (urban, suburban, or rural).

For Urban area:

- For Small and Medium City:

$$a(h_m) = [1.1\log(f_c) - 0.7]h_m - [1.56\log(f_c) - 0.8] \ldots (4)$$

$$C = 0$$

- For large City (metropolitan):

$$a(h_m) = 8.29\,[\log(1{,}54h_m)]^2 - 1{,}1 \quad \text{for } f_c \le 300\text{ MHz} \ldots (5)$$

$$a(h_m) = 3.2\,[\log(11.75h_m)]^2 - 4.97 \quad \text{for } f_c \ge 300\text{ MHz} \ldots (6)$$

$$C = 0$$

For Suburban area:

$$C = -2[\log(f_c/28)]^2 - 5.4 \ldots (7)$$

For Rural area:

$$C = -4.78[\log(f_c)]^2 + 18.33\log(f_c) - 40.98 \ldots (8)$$

where *a(hm)* of Suburban and Rural is equal to the *a(hm)* of Urban Small and Medium City.
where,
f_c = carrier frequency[MHz]
d = distance between Base Transceiver Station (BTS) and Mobile Station (MS) [Km]
h_b= antenna height of BTS [m]
h_m =antenna height of MS [m]

B. *COST-231 Ref: [1], [3],[4]*
Most future PCS systems are expected to operate in the 1800-2000 MHz frequency band. It has been shown that path loss can be more dramatic at these frequencies than those in the 900 MHz range. Some studies have suggested that the path loss experienced at 1845 MHz is approximately 10 dB larger than those experienced at 955 MHz, all other parameters being kept constant. The COST231-Hata model extends Hata's model for use in the 1500-2000 MHz frequency range, where it is known to underestimate path loss. The model is expressed in terms of the following parameters
Carrier Frequency (fc) 1500-2000 MHz.
BS Antenna Height (hb) 30-200 m
MS Antenna Height (hm) 1-10 m
Transmission Distance (d) 1-20 km
The path loss according to the COST-231-Hata model is expressed as:

$$P_L[dB] = A + B\log(d) + C \ldots\ldots(9) = (1)$$

where:

$$A = 46.3 + 33.9\log(f_c) - 13.82\log(h_b) - a(h_m)\ldots(10)$$

B is the same in (3) namely:

$$B = 44.9 - 6.55\log(h_b)\ldots(11) = (3)$$

$a(h_m)$ is the same in (4), (5) dan (6) above, with the area classification is as follows:
For Urban area:
For Small and Medium City:

$$a(h_m) = [1.1\log(f_c) - 0.7]h_m - [1.56\log(f_c) - 0.8]\ldots(12)$$

For large urban (metropolitan), because of restrictions on the frequency of COST-231 model is 1500-2000 MHz, then the equation which meets this restrictionsis the equation (6) as follows:

$$a(h_m) = 3.2[\log(11.75\,h_m)]^2 - 4.97 \text{ for } f_c \geq 300\text{MHz}\ldots(13)$$

While the value of C to be inserted into the equation (9) of the COST-231 model is as follows:

$$C = \begin{cases} 0\,dB \rightarrow \text{for Small and medium city} \\ 3\,dB \rightarrow \text{for Metropolitan City} \end{cases}$$

III. Methodology

The tools used are Matlab Software and Microsoft Excel.The main variables to be cocerned is the Mobile Station antenna height factor $a(h_m)$. The other variables for simulating various possibilities are the distance form BTS to MS (d), frequency (f), and antenna height of BTS (h_b). The final variable which measures the results of this study is *pathloss*.In this research, simulation is restricted to the propagation model as follows:

1. Okumura - Hata Model for Urban area Medium Small City.
2. Okumura - Hata Model for Urban area Lage City (Metropolitan) for $f_c \leq 300$ MHz.
3. Okumura - Hata Model for Urban area Lage City (Metropolitan) for $f_c \geq 300$ MHz.
4. Okumura - Hata Model for Suburban area.
5. Okumura - Hata Model for Open area.
6. COST-231 Model for Urban area Medium Small City.

In each propagation models, the simulation would be done for 7 cases, namely:
Case 1: d constant, f constant, h_b constan, h_m varied.
Case 2: d constant, f constant, h_b varied, h_m varied.
Case 3: d constant, f varied, h_b constant, h_m varied.
Case 4: d varied, f constant, h_b constant, h_m varied.
Case 5: d varied, f varied, h_b constant, h_m constant
Case 6: d varied, f constant, h_b varied, h_m constant.
Case 7: d constant, f varied, h_b varied, h_m constant.
to examine the influence of a mobile station antenna height (h_m) against the ***path loss***, then the simulations were grouped into two categories. The first category is z1: Including a (hm), and the second category is z2: without a (hm).

IV. Results

1. Okumura - Hata Model for Urban area Medium Small City

Chart 1.1a : Path Loss average in Okumura - Hata Model for Urban area Medium Small City - **<u>Case 1</u>**: d constant, f constant, hb constan, hm varied.

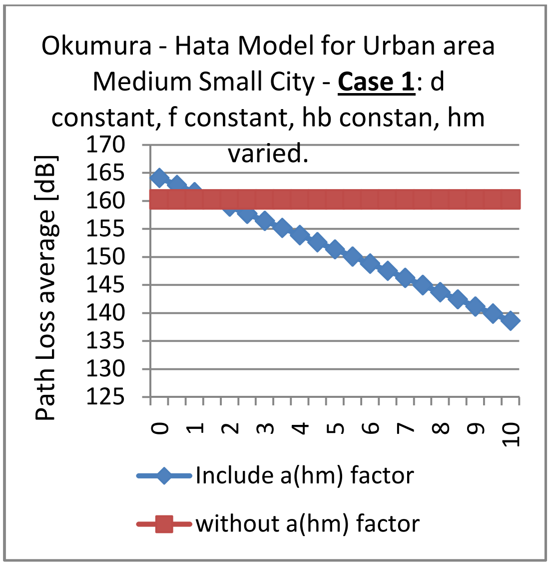

Fig. 1 Example of an unacceptable low-resolution image

Chart 1.1b : Path Loss average in Okumura - Hata Model for Urban area Medium Small City - **Case 2**: d constant, f constant, hb varied, hm varied.

z1: Including a(hm) factor ; z2: Without a(hm) factor.

```
% x = hm varied [in meters]:
% y = hb varied [in meters];
% f = Frequency (fc) [in MHz];
% d = distance [in Km) ;
% a = a(hm) = 8.29*((log(1.54*hm))^2)-1.1;
% z = Path Loss (PL) [in dB(s)];
[y,x] = meshgrid(5:.5:45,0:.5:10);
d = 10; f = 900;
a = 8.29*((log(1.54*x)).^2)-1.1;
B = 44.9-6.55*log(y);
A1 = 69.55+26.16*(log(f))-13.82*log(y)-a;
A2 = 69.55+26.16*(log(f))-13.82*log(y);
C = 0;
z1 = A1 + B*log(d) + C;
z2 = A2 + B*log(d) + C;
figure(1)
mesh(x, y, z1)
hold on
mesh(x, y, z2)
hold off
grid on
colormap hsv
alpha(0.5)
title('\it Path Loss (d constant, f constant, hb varied, hm varied) z1: with a(hm) and z2: without a(hm)')
xlabel('\it x = hm [meters]')
ylabel('\it y = hb [kilo meters]')
zlabel('\it z = Path Loss (PL) [in dB(s)]')
```

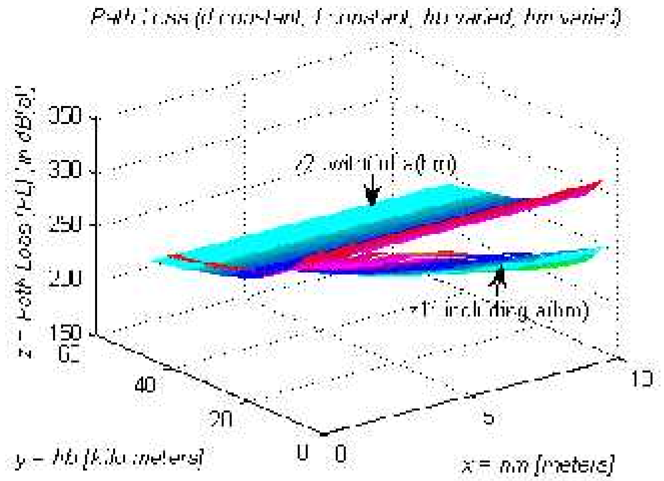

Chart 1.1c : Path Loss average in Okumura - Hata Model for Urban area Medium Small City - **Case 3**: d constant, f varied, hb constant, hm varied.

z1: Including a(hm) factor ; z2: Without a(hm) factor.

```
%Suppose: a(hm)= a = 8,29 [log(1,54h_m)]^2-1,1;
% x=hm varied [in meters] ; y = f varied [in MHz];
% hb constan [in meters] ; distance d constant [in Km) ;
% a = a(hm) = 8.29*((log(1.54*hm))^2)-1.1;
% z = Path Loss (PL) [in dB(s)];
[y,x] = meshgrid(600:20:1000,  0:.5:10);
hb = 35;
d = 10;
a = 8.29*((log(1.54*x)).^2)-1.1;
B = 44.9-6.55*log(hb);
A1 = 69.55+26.16*(log(y))-13.82*log(hb)-a;
A2 = 69.55+26.16*(log(y))-13.82*log(hb);
C = 0;
z1 = A1 + B*log(d) + C;
z2 = A2 + B*log(d) + C;
figure(1)
mesh(x, y, z1)
hold on
mesh(x, y, z2)
hold off
grid on
colormap hsv
alpha(0.5)
title('\it Path Loss (d constant, f varied, hb constant, hm varied)')
xlabel('\it x = hm [meters]')
ylabel('\it y = f [MHz]')
zlabel('\it z = Path Loss (PL) [in dB(s)]')
```

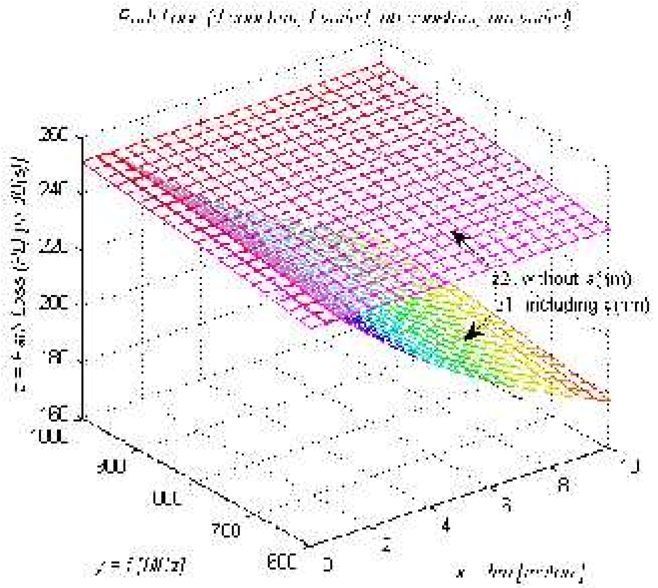

Chart 1.1d : Path Loss average in Okumura - Hata Model for Urban area Medium Small City - **Case 4**: d varied, f constant, hb constant, hm varied.

z1: Including a(hm) factor ; z2: Without a(hm) factor.

```
% x = hm varied [in meters] ; y = d varied [in Km];
% hb constan [in meters] ; frequency f constant [in MHz) ;
% a = a(hm) = 8.29*((log(1.54*hm))^2)-1.1;
% z = Path Loss (PL) [in dB(s)];
[y,x] = meshgrid(3:2:43,  0:.5:10);
f = 900;
hb = 35;
a = 8.29*((log(1.54*x)).^2)-1.1;
B = 44.9-6.55*log(hb);
A1 = 69.55+26.16*(log(f))-13.82*log(hb)-a;
A2 = 69.55+26.16*(log(f))-13.82*log(hb);
C = 0;
```

```
z1 = A1 + B*log(y) + C;
z2 = A2 + B*log(y) + C;
figure(1)
mesh(x, y, z1)
hold on
mesh(x, y, z2)
hold off
grid on
colormap hsv
alpha(0.5)
title('\it Path Loss (d varied, f constant, hb constant, hm varied)')
xlabel('\it x = hm [meters]')
ylabel('\it y = d [Km]')
zlabel('\it z = Path Loss (PL) [in dB(s)]')
```

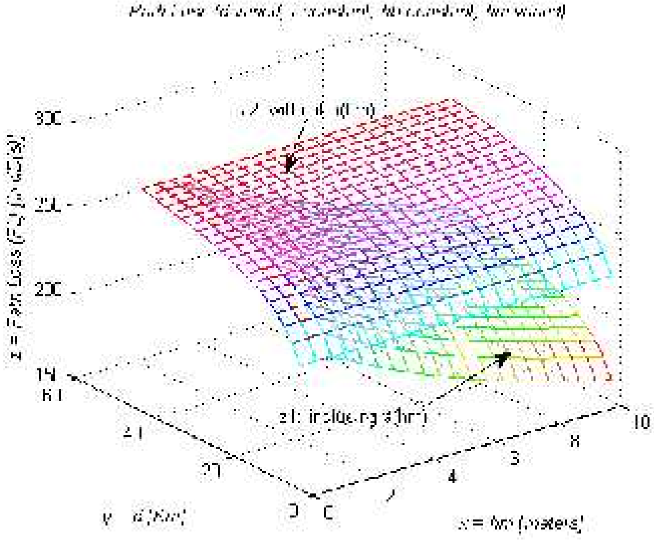

Chart 1.1e : Path Loss average in Okumura - Hata Model for Urban area Medium Small City - **Case 5**: d varied, f varied, hb constant, hm constant.

z1: Including a(hm) factor ; z2: Without a(hm) factor.

```
% x = d varied [in kilometers] ; y = f varied [in MHz];
% hb constan [in meters] ; hm constant [in meters) ;
% a = a(hm) = 8.29*((log(1.54*hm))^2)-1.1;
% z = Path Loss (PL) [in dB(s)];
[y,x] = meshgrid(600:20:1000,  3:2:43);
hm = 1.5;
hb = 35;
a = 8.29*((log(1.54*hm)).^2)-1.1;
B = 44.9-6.55*log(hb);
A1 = 69.55+26.16*(log(y))-13.82*log(hb)-a;
A2 = 69.55+26.16*(log(y))-13.82*log(hb);
C = 0;
z1 = A1 + B*log(x) + C;
z2 = A2 + B*log(x) + C;
figure(1)
mesh(x, y, z1)
hold on
mesh(x, y, z2)
hold off
grid on
colormap hsv
alpha(0.5)
title('\it Path Loss (d varied, f varied, hb constant, hm constant)')
xlabel('\it x = d [kilometers]')
ylabel('\it y = f [MHz]')
zlabel('\it z = Path Loss (PL) [in dB(s)]')
```

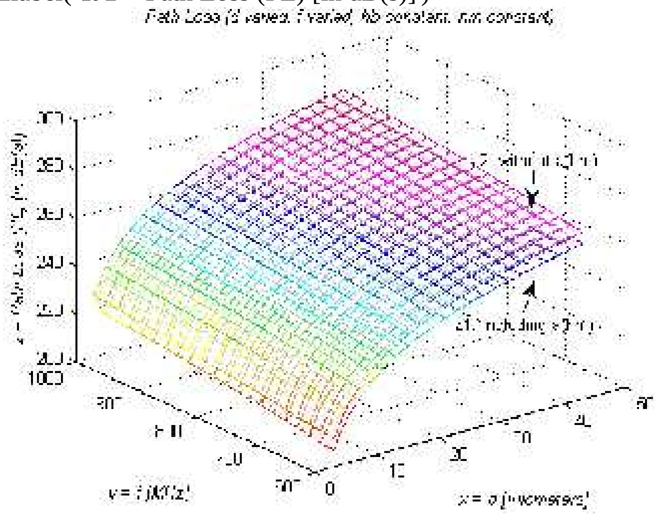

Chart 1.1f : Path Loss average in Okumura - Hata Model for Urban area Medium Small City - **Case 6**: d varied, f constant, hb varied, hm constant.

z1: Including a(hm) factor ; z2: Without a(hm) factor.

```
% x = d varied [in kilometers] ; y = hb varied [in meters];
% f constan [in MHz] ; hm constant [in meters) ;
% a = a(hm) = 8.29*((log(1.54*hm))^2)-1.1;
% z = Path Loss (PL) [in dB(s)];
[y,x] = meshgrid(5:2:45,  3:2:43);
hm = 1.5;
f = 900;
a = 8.29*((log(1.54*hm)).^2)-1.1;
B = 44.9-6.55*log(y);
A1 = 69.55+26.16*(log(f))-13.82*log(y)-a;
A2 = 69.55+26.16*(log(f))-13.82*log(y);
C = 0;
z1 = A1 + B*log(x) + C;
z2 = A2 + B*log(x) + C;
figure(1)
mesh(x, y, z1)
hold on
mesh(x, y, z2)
hold off
grid on
colormap hsv
alpha(0.5)
title('\it Path Loss (d varied, f varied, hb constant, hm constant)')
xlabel('\it x = d [kilometers]')
ylabel('\it y = f [MHz]')
zlabel('\it z = Path Loss (PL) [in dB(s)]')
```

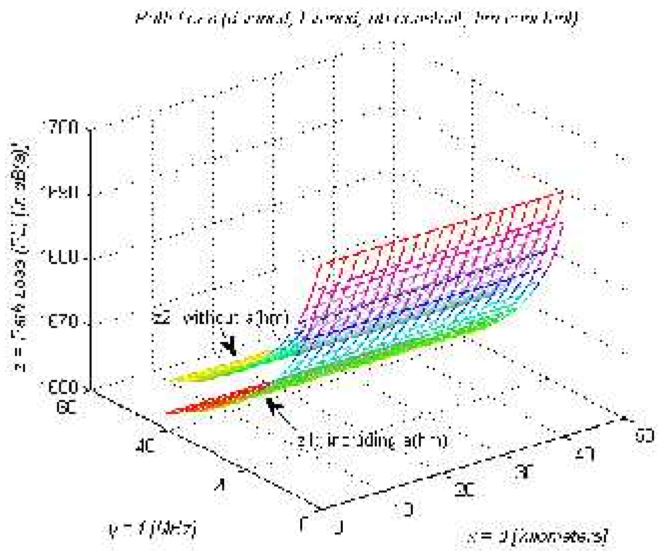

Chart 1.1g : Path Loss average in Okumura - Hata Model for Urban area Medium Small City - **Case 7**: d constant, f varied, hb varied, hm constant.
z1: Including a(hm) factor ; z2: Without a(hm) factor.

```
% x = f varied [in MHz] ; y = hb varied [in meters];
% d constan [in kilometers] ; hm constant [in meters) ;
% a = a(hm) = 8.29*((log(1.54*hm))^2)-1.1;
% z = Path Loss (PL) [in dB(s)];
[y,x] = meshgrid(600:20:1000,  5:2:45);
hm = 1.5;
d = 10;
a = 8.29*((log(1.54*hm)).^2)-1.1;
B = 44.9-6.55*log(y);
A1 = 69.55+26.16*(log(x))-13.82*log(y)-a;
A2 = 69.55+26.16*(log(x))-13.82*log(y);
C = 0;
z1 = A1 + B*log(d) + C;
z2 = A2 + B*log(d) + C;
figure(1)
mesh(x, y, z1)
hold on
mesh(x, y, z2)
hold off
grid on
colormap hsv
alpha(0.5)
title('\it Path Loss (d constant, f varied, hb varied, hm constant)')
xlabel('\it x = f [MHz]')
ylabel('\it y = hb [meters]')
zlabel('\it z = Path Loss (PL) [in dB(s)]')
```

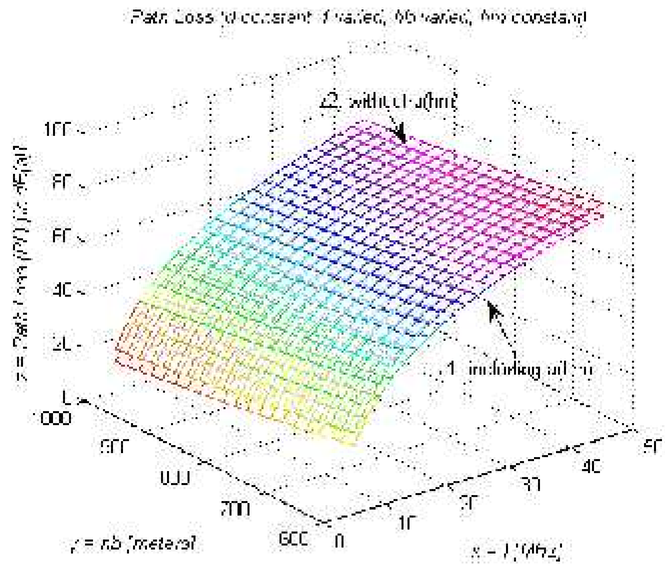

TABLE I
Path Loss in Okumura - Hata Model for Urban area Medium Small City

No.	Case	Path Loss average [dB]		difference [%]
		z1: Include a(hm) factor	z2: without a(hm) factor	
1	Case-1	151,341	160,280	5,58%
2	Case-2	155,704	164,644	5,43%
3	Case-3	149,869	158,809	5,63%
4	Case-4	160,867	169,807	5,26%
5	Case-5	168,325	168,336	0,01%
6	Case-6	173,997	174,013	0,01%
7	Case-7	163,162	163,172	0,01%
the average of difference between z1 and z2				3,13%

2. **Okumura - Hata Model for Urban area Lage City (Metropolitan) for fc ≤300 MHz.**

Idem, then the result is described in the following table.

TABLE III
Path Loss in Okumura - Hata Model for Urban area Large City (Metropolitan) for fc ≤300 MHz.

No.	Case	Path Loss average [dB]		difference [%]
		z1: Include a(hm) factor	z2: without a(hm) factor	
1	Case-1	139,470	145,727	4,29%
2	Case-2	143,833	150,091	4,17%
3	Case-3	**156,2853**	**161,6533**	3,32%
4	Case-4	148,997	155,254	4,03%
5	Case-5	152,153	152,149	0,00%
6	Case-6	159,464	159,460	0,00%

7	Case-7	163,176	163,172	0,00%
the average of difference between z1 and z2				2,26%

3. Okumura - Hata Model for Urban area Lage City (Metropolitan) for fc ⩾300 MHz.

Idem, then the result is described in the following table.

TABLE IIIII

Path Loss in Okumura - Hata Model for Urban area Large City (Metropolitan) for fc ≥300 MHz.

No .	Case	Path Loss average [dB]		differen ce [%]
		z1: Include a(hm) factor	z2: without a(hm) factor	
1	Case-1	156,071	160,280	2,63%
2	Case-2	160,434	164,644	2,56%
3	Case-3	155,350	159,559	2,64%
4	Case-4	165,598	169,807	2,48%
5	Case-5	169,087	169,086	0,00%
6	Case-6	174,014	174,013	0,00%
7	Case-7	163,923	163,922	0,00%
the average of difference between z1 and z2				1,47%

4. Okumura - Hata Model for Suburban area.

Idem, then the result is described in the following table.

TABLE IV

Path Loss in Okumura - Hata Model for Suburban area.

No .	Case	Path Loss average [dB]		differen ce [%]
		z1: Include a(hm) factor	z2: without a(hm) factor	
1	Case-1	141,397	150,338	5,95%
2	Case-2	145,760	154,701	5,78%
3	Case-3	140,372	149,730	6,25%
4	Case-4	150,924	159,864	5,59%
5	Case-5	159,243	159,257	0,01%
6	Case-6	164,054	164,070	0,01%
7	Case-7	154,0798	154,0932	0,01%
the average of difference between z1 and z2				3,37%

5. Okumura - Hata Model for Open area.

Idem, then the result is described in the following table.

TABLE V

Path Loss in Okumura - Hata Model for Open area.

No .	Case	Path Loss average [dB]		differen ce [%]
		z1: Include a(hm) factor	z2: without a(hm) factor	
1	Case-1	122,793	131,734	6,79%
2	Case-2	127,156	136,097	6,57%
3	Case-3	121,802	131,160	7,13%
4	Case-4	120,653	129,594	6,90%
5	Case-5	140,673	140,687	0,01%
6	Case-6	145,451	145,467	0,01%
7	Case-7	154,080	154,093	0,01%
the average of difference between z1 and z2				3,92%

6. COST-231 Model for Urban area Medium Small City.

Idem, then the result is described in the following table.

TABLE VI

Path Loss in COST-231 Model for urban area Medium Small City.

No .	Case	Path Loss average [dB]		differen ce [%]
		z1: Include a(hm) factor	z2: without a(hm) factor	
1	Case-1	117,199	127,506	8,08%
2	Case-2	117,426	127,734	8,07%
3	Case-3	116,513	126,711	8,05%
4	Case-4	115,243	125,550	8,21%
5	Case-5	124,714	124,755	0,03%
6	Case-6	125,214	125,261	0,04%
7	Case-7	146,850	146,891	0,03%
the average of difference between z1 and z2				4,64%

Each of the 6 propagation models had been run in 7 different cases. So, there are 42 simulation results, but for the reason of efficiency, only 7 charts is presented, namely the result of 7 case in propagation model 1 (Okumura - Hata Model for Urban area Medium Small City). However, the recapitulation of all simulation result is presented by Table I until Table VI, where every table represents each propagation models, with 7 cases respectivly. There is interesting thing about case number 5, 6, and 7 in each models, namely the difference value between z1 and z2 is almost zero or zeros. In these case, the value of $a(h_m)$ is determined to be constant at 1.5 meters. When the value of $a(h_m)$ is under or upper 1.5 meters then the different value of Z1 and Z2 is higher.

V. Conclusions

The very least value of pathloss difference between 2 compared models occurs when the Mobile Station antenna height is 1.5 meters. It means that when the assumption of Mobile Station antenna height is 1.5 meters, then it is not important to include *a(hm)* factor because its effect to the pathloss is very insignificant, where the different mean value is 0,0024%.

ACKNOWLEDGMENT

I would like to thank to a person who has the nick name Star Strider on an online Mathwork community forum (with the url: https://www.mathworks.com/matlabcentral/profile/authors/99682-star-strider), for his/ her contribution of giving any suggestion of my questions. Thanks also to everyone who has giving any contribution to this paper.

REFERENCES

[1] Theodore S. Rappaport. *Wireless Communications Principle and Practice.*

[2] Sindak Hutauruk - *Simulasi Model Empiris Okumura-Hata dan Model COST 231 untuk Rugi-rugi Saluran pada Komunikasi Selular*. Seminar Nasional Teknologi Informasi & Komunikasi Terapan 2011 (Semantik 2011) ISBN 979-26-0255-0.

[3] Comparison of Okumura, Hata and COST-231 Models on the Basis of Path Loss and Signal Strength.

[4] Comparative Analysis of Different Parameters in Propagation Model for Mobile Communication System.

[5] William C. Y. Lee. *Mobile Communications Design Fundamentals.*