Experiment 4: To Analyse Outdoor Path Loss Models

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Aim:

To study the Outdoor Path loss models and estimate the path loss

Problem statement 1:

Estimate the path loss using Hata Model and plot distance Vs. Path loss.
Use the following values:

i. Frequency of operation f1 = 700 MHz, f2 = 900 MHz
ii. hte = 30m, hre = 1.5m
iii. Distance = 1:2:20 km
iv. Consider urban (medium and large city), sub-urban and rural.

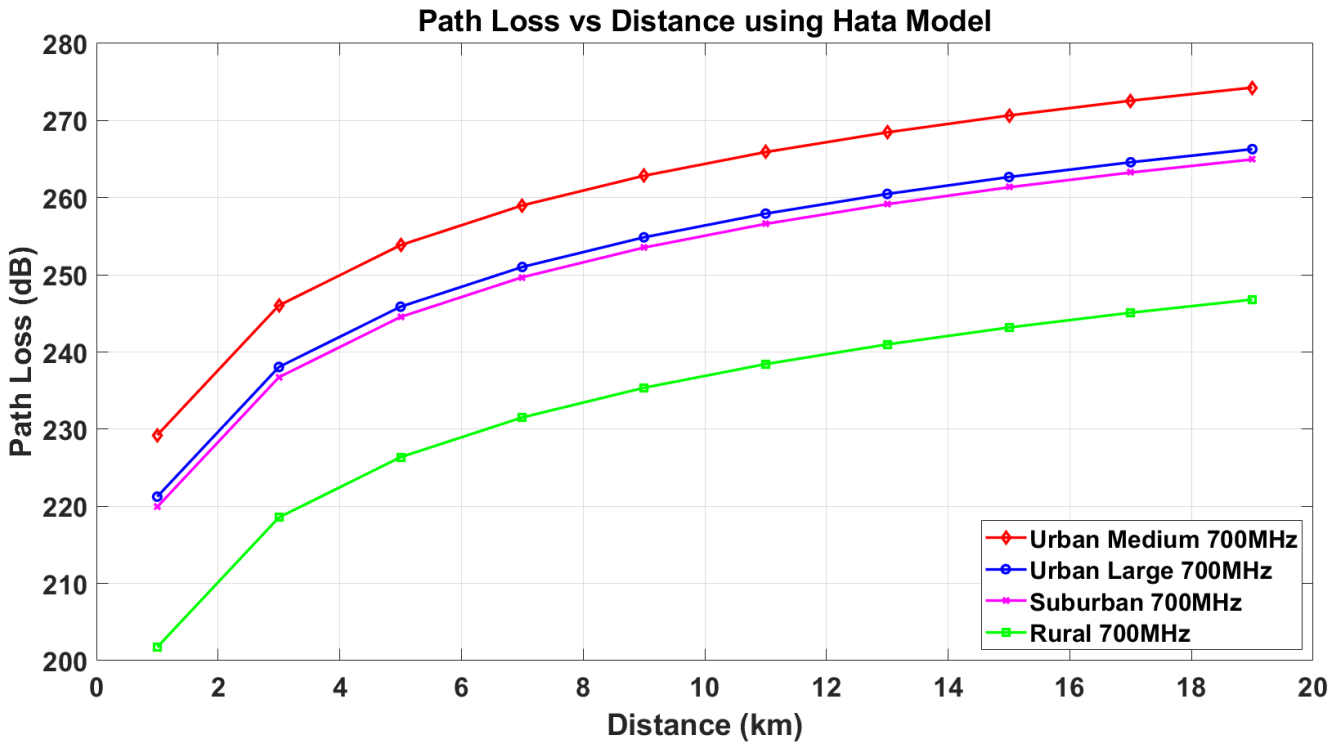
Code:

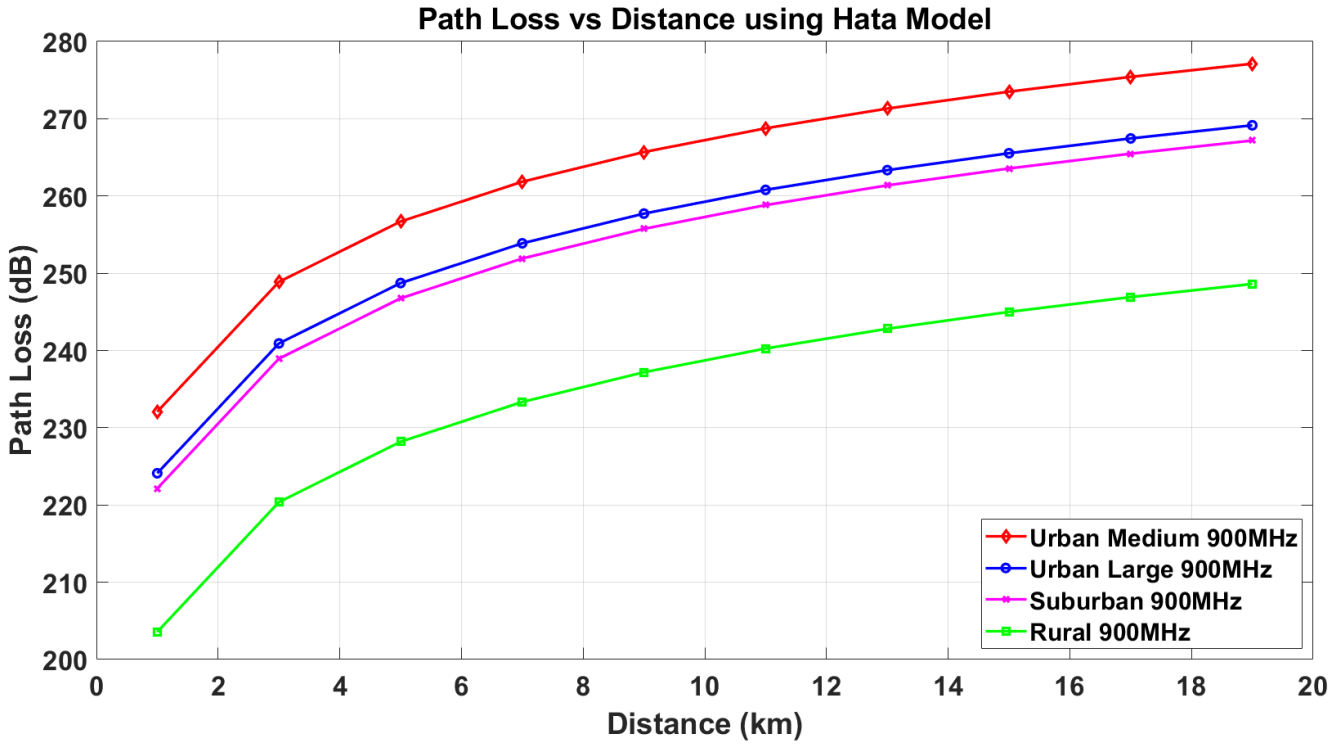
```
clc
clear all
close all

f = 700;              % Freq of operation, 1
ht = 30;              % height of transmitting antenna
d = 1:2:20;           % Distance vector (1 km to 20 km with a step of 2 km)
d_meters = d * 1000; % kilometers to meters
hr = 1.5;             % Height of the receiving antenna (in meters)
% alpha
a_hr = (1.1*log10(f) - 0.7)*hr - (1.56*log10(f) - 0.8);
if f > 300
   a_hr_1 = (8.29*log10(1.54*hr))^2-1.1;
else
    a_hr_1 = (3.2*log10(11.75*hr))^2-4.97;
end

path_loss_urban_medium = 69.55 + 26.16*log10(f) - 13.82*log10(ht) - a_hr + (44.9 -
6.55*log10(ht))*log10(d_meters);
path_loss_urban_large = 69.55 + 26.16*log10(f) - 13.82*log10(ht) - a_hr_1 + (44.9
- 6.55*log10(ht))*log10(d_meters);
path_loss_suburban = 69.55 + 26.16*log10(f) - 13.82*log10(ht) - a_hr + (44.9 -
6.55*log10(ht))*log10(d_meters) - 2*(log10(f/28))^2 - 5.4;
path_loss_rural = 69.55 + 26.16*log10(f) - 13.82*log10(ht) - a_hr + (44.9 -
6.55*log10(ht))*log10(d_meters) - 4.78*(log10(f))^2 + 18.33*log10(f) - 40.94;
```

```
% Plotting
figure;
plot(d, path_loss_urban_medium, '-d', 'DisplayName', 'Urban Medium 700MHz',
'LineWidth', 2, 'Color', 'red');
hold on
plot(d, path_loss_urban_large, '-o', 'DisplayName', 'Urban Large 700MHz',
'LineWidth', 2, 'Color', 'blue');
plot(d, path_loss_suburban, '-x', 'DisplayName', 'Suburban 700MHz' ,'LineWidth',
2, 'Color', 'magenta');
plot(d, path_loss_rural, '-s', 'DisplayName', 'Rural 700MHz', 'LineWidth', 2,
'Color', 'green');
grid on;

% Labels and title
xlabel('Distance (km)');
ylabel('Path Loss (dB)');
title('Path Loss vs Distance using Hata Model');
legend('Location', 'southeast');
set(gca,'FontWeight','bold','FontSize',20);
disp("f = 700 MHz");
disp("Urban Medium:");
disp(path_loss_urban_medium);
disp("Urban Large:");
disp(path_loss_urban_large);
disp("Suburban:");
disp(path_loss_suburban);
disp("Rural:");
disp(path_loss_rural);


f = 900;              %Freq of operation, 2
%alpha recalculation
a_hr = (1.1*log10(f) - 0.7)*hr - (1.56*log10(f) - 0.8);
if f > 300
   a_hr_1 = (8.29*log10(1.54*hr))^2-1.1;
else
    a_hr_1 = (3.2*log10(11.75*hr))^2-4.97;
end

path_loss_urban_medium = 69.55 + 26.16*log10(f) - 13.82*log10(ht) - a_hr + (44.9 -
6.55*log10(ht))*log10(d_meters);
path_loss_urban_large = 69.55 + 26.16*log10(f) - 13.82*log10(ht) - a_hr_1 + (44.9
- 6.55*log10(ht))*log10(d_meters);
path_loss_suburban = 69.55 + 26.16*log10(f) - 13.82*log10(ht) - a_hr + (44.9 -
6.55*log10(ht))*log10(d_meters) - 2*(log10(f/28))^2 - 5.4;
path_loss_rural = 69.55 + 26.16*log10(f) - 13.82*log10(ht) - a_hr + (44.9 -
6.55*log10(ht))*log10(d_meters) - 4.78*(log10(f))^2 + 18.33*log10(f) - 40.94;

% Plotting
figure;
plot(d, path_loss_urban_medium, '-d', 'DisplayName', 'Urban Medium 900MHz',
'LineWidth', 2, 'Color', 'red');
hold on;
plot(d, path_loss_urban_large, '-o', 'DisplayName', 'Urban Large 900MHz',
'LineWidth', 2, 'Color', 'blue');
plot(d, path_loss_suburban, '-x', 'DisplayName', 'Suburban 900MHz' ,'LineWidth',
2, 'Color', 'magenta');
```

```
plot(d, path_loss_rural, '-s', 'DisplayName', 'Rural 900MHz', 'LineWidth', 2,
'Color', 'green');
grid on;

% Labels and title
xlabel('Distance (km)');
ylabel('Path Loss (dB)');
title('Path Loss vs Distance using Hata Model');
legend('Location', 'southeast');
set(gca,'FontWeight','bold','FontSize',20);
disp("f = 900 MHz");
disp("Urban Medium:");
disp(path_loss_urban_medium);
disp("Urban Large:");
disp(path_loss_urban_large);
disp("Suburban:");
disp(path_loss_suburban);
disp("Rural:");
disp(path_loss_rural);
```

Output:


Path Loss vs Distance using Hata Model
Path Loss (dB)
Distance (km)
Urban Medium 700MHz
Urban Large 700MHz
Suburban 700MHz
Rural 700MHz


Path Loss vs Distance using Hata Model
Path Loss (dB)
Distance (km)
Urban Medium 900MHz
Urban Large 900MHz
Suburban 900MHz
Rural 900MHz

Command Window Output:

f = 700 MHz

Urban Medium:

229.2325 246.0390 253.8536 259.0009 262.8455 265.9154 268.4710 270.6601 272.5748 274.2764

Urban Large:

221.2523 238.0588 245.8734 251.0207 254.8653 257.9352 260.4907 262.6799 264.5946 266.2962

Suburban:

219.9240 236.7305 244.5451 249.6924 253.5370 256.6069 259.1625 261.3516 263.2664 264.9679

Rural:

201.7510 218.5575 226.3721 231.5195 235.3641 238.4339 240.9895 243.1786 245.0934 246.7949

f = 900 MHz

Urban Medium:

232.0779 248.8844 256.6990 261.8463 265.6909 268.7608 271.3163 273.5055 275.4202 277.1218

Urban Large:

224.1075 240.9140 248.7286 253.8759 257.7205 260.7904 263.3460 265.5351 267.4499 269.1514

Suburban:

222.1352 238.9418 246.7564 251.9037 255.7483 258.8182 261.3737 263.5629 265.4776 267.1792

Rural:

203.5714 220.3780 228.1926 233.3399 237.1845 240.2543 242.8099 244.9991 246.9138 248.6153

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Inference:

i. Path loss increases with an increase in distance
ii. Path loss increases slightly with increase in frequency, in all environments (from 700 to 900 MHz)

Problem statement 2:

Estimate the path loss using Hata Model and plot Transmitting antenna height Vs. Path loss
Use the following values:

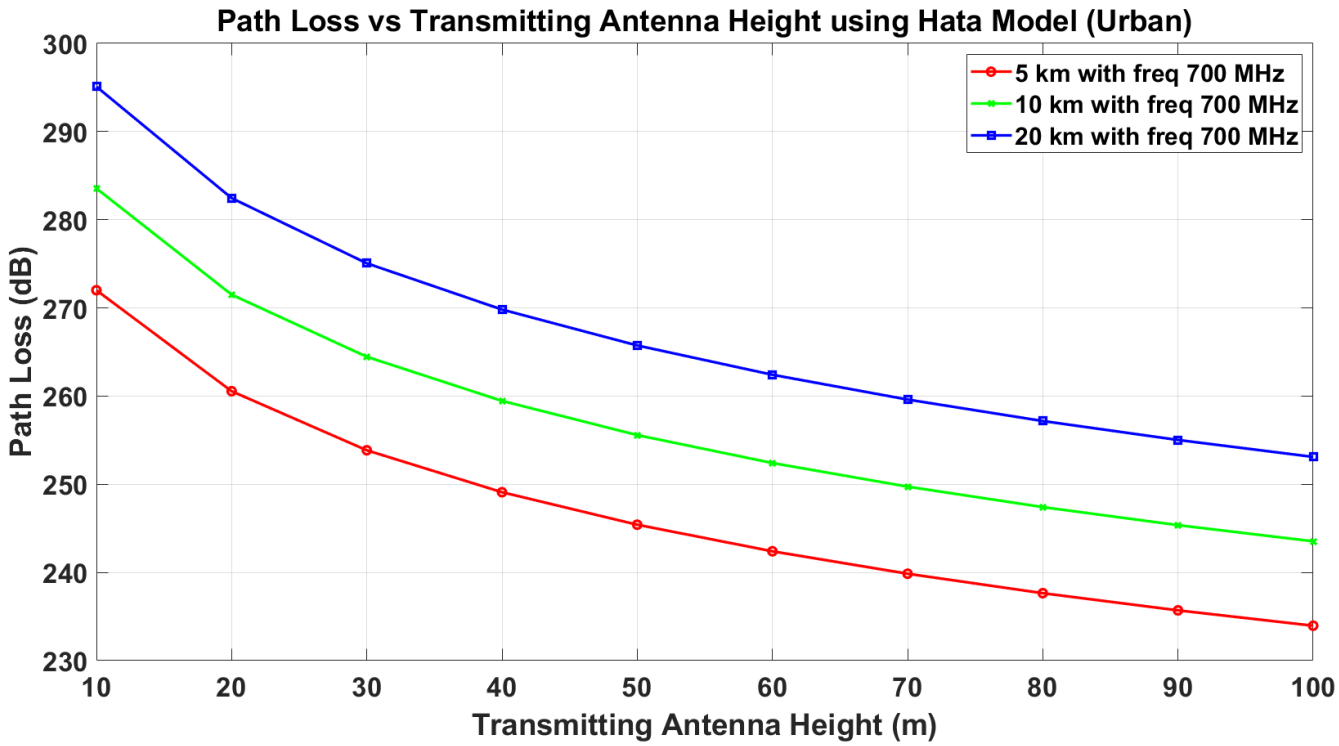
i. Frequency of operation f = 700 MHz
ii. hre = 1.5m
iii. Distance d1= 5 km, d2 = 10km, d3 = 20km
iv. hte = 10:10:100 m
v. Consider urban environment

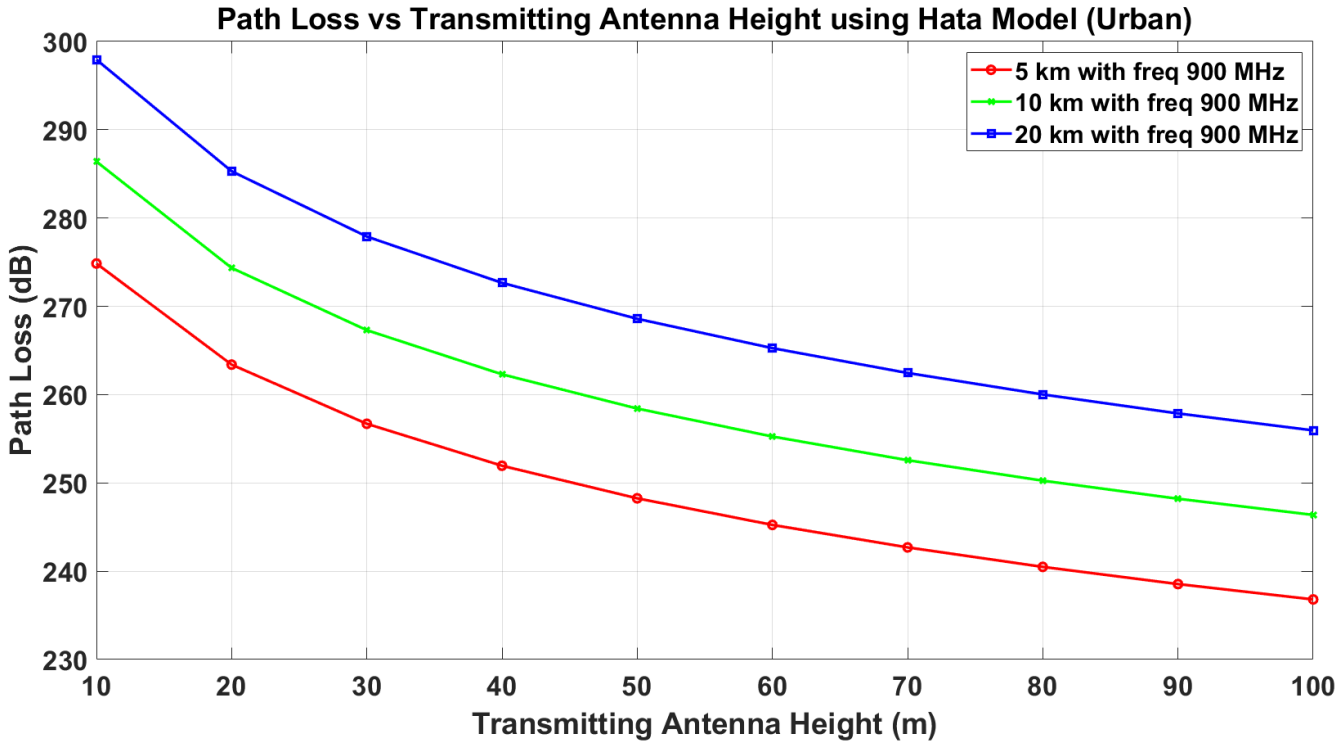
Code:

```
clc
clear all
close all

f = 700;
hr = 1.5;
d = [5, 10, 20];
d_meters = d * 1000;
ht = 10:10:100;

path_loss_d1 = zeros(size(ht));
path_loss_d2 = zeros(size(ht));
path_loss_d3 = zeros(size(ht));

for i = 1:length(ht)
    a_hr = (1.1*log10(f) - 0.7)*hr - (1.56*log10(f) - 0.8);
    path_loss_d1(i) = 69.55 + 26.16*log10(f) - 13.82*log10(ht(i)) - a_hr + (44.9 -
6.55*log10(ht(i)))*log10(d_meters(1));
    path_loss_d2(i) = 69.55 + 26.16*log10(f) - 13.82*log10(ht(i)) - a_hr + (44.9 -
6.55*log10(ht(i)))*log10(d_meters(2));
    path_loss_d3(i) = 69.55 + 26.16*log10(f) - 13.82*log10(ht(i)) - a_hr + (44.9 -
6.55*log10(ht(i)))*log10(d_meters(3));
end

figure;
plot(ht, path_loss_d1, '-o', 'DisplayName', '5 km with freq 700 MHz', 'LineWidth',
2, 'Color', 'red');
hold on;
plot(ht, path_loss_d2, '-x', 'DisplayName', '10 km with freq 700 MHz',
'LineWidth', 2, 'Color', 'green');
plot(ht, path_loss_d3, '-s', 'DisplayName', '20 km with freq 700 MHz',
'LineWidth', 2, 'Color', 'blue');
grid on;

xlabel('Transmitting Antenna Height (m)');
ylabel('Path Loss (dB)');
title('Path Loss vs Transmitting Antenna Height using Hata Model (Urban)');
legend('Location', 'northeast');
set(gca,'FontWeight','bold','FontSize',20);
disp("Freq = 700 MHz");
disp("Distance = 5 km");
disp(path_loss_d1);
```

```
disp("Distance = 10 km");
disp(path_loss_d2);
disp("Distance = 20 km");
disp(path_loss_d2);


f = 900;

for i = 1:length(ht)
    a_hr = (1.1*log10(f) - 0.7)*hr - (1.56*log10(f) - 0.8);
    path_loss_d1(i) = 69.55 + 26.16*log10(f) - 13.82*log10(ht(i)) - a_hr + (44.9 -
6.55*log10(ht(i)))*log10(d_meters(1));
    path_loss_d2(i) = 69.55 + 26.16*log10(f) - 13.82*log10(ht(i)) - a_hr + (44.9 -
6.55*log10(ht(i)))*log10(d_meters(2));
    path_loss_d3(i) = 69.55 + 26.16*log10(f) - 13.82*log10(ht(i)) - a_hr + (44.9 -
6.55*log10(ht(i)))*log10(d_meters(3));
end

figure;
plot(ht, path_loss_d1, '-o', 'DisplayName', '5 km with freq 900 MHz', 'LineWidth',
2, 'Color', 'red');
hold on;
plot(ht, path_loss_d2, '-x', 'DisplayName', '10 km with freq 900 MHz',
'LineWidth', 2, 'Color', 'green');
plot(ht, path_loss_d3, '-s', 'DisplayName', '20 km with freq 900 MHz',
'LineWidth', 2, 'Color', 'blue');
grid on;

xlabel('Transmitting Antenna Height (m)');
ylabel('Path Loss (dB)');
title('Path Loss vs Transmitting Antenna Height using Hata Model (Urban)');
legend('Location', 'northeast');
set(gca,'FontWeight','bold','FontSize',20);
disp("Freq = 900 MHz");
disp("Distance = 5 km");
disp(path_loss_d1);
disp("Distance = 10 km");
disp(path_loss_d2);
disp("Distance = 20 km");
disp(path_loss_d2);
```

Output:


Path Loss vs Transmitting Antenna Height using Hata Model (Urban)
5 km with freq 700 MHz
10 km with freq 700 MHz
20 km with freq 700 MHz
Path Loss (dB)
Transmitting Antenna Height (m)
300
290
280
270
260
250
240
230
10
20
30
40
50
60
70
80
90
100


Path Loss vs Transmitting Antenna Height using Hata Model (Urban)
5 km with freq 900 MHz
10 km with freq 900 MHz
20 km with freq 900 MHz
Path Loss (dB)
Transmitting Antenna Height (m)
300
290
280
270
260
250
240
230
10
20
30
40
50
60
70
80
90
100

Command Window Output:

Freq = 700 MHz

Distance = 5 km

272.0072 260.5535 253.8536 249.0999 245.4126 242.3999 239.8527 237.6462 235.6999 233.9590

Distance = 10 km

283.5517 271.5045 264.4573 259.4573 255.5789 252.4101 249.7309 247.4100 245.3629 243.5317

Distance = 20 km

283.5517 271.5045 264.4573 259.4573 255.5789 252.4101 249.7309 247.4100 245.3629 243.5317

Freq = 900 MHz

Distance = 5 km

274.8526 263.3989 256.6990 251.9453 248.2580 245.2453 242.6981 240.4916 238.5453 236.8043

Distance = 10 km

286.3971 274.3499 267.3027 262.3027 258.4243 255.2555 252.5763 250.2554 248.2083 246.3771

Distance = 20 km

286.3971 274.3499 267.3027 262.3027 258.4243 255.2555 252.5763 250.2554 248.2083 246.3771

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Inference:

i. Path loss decreases with an increase in Transmitting Antenna Height
ii. Path loss increases slightly with increase in frequency, in all environments (from 700 to 900 MHz)

Problem statement 3:

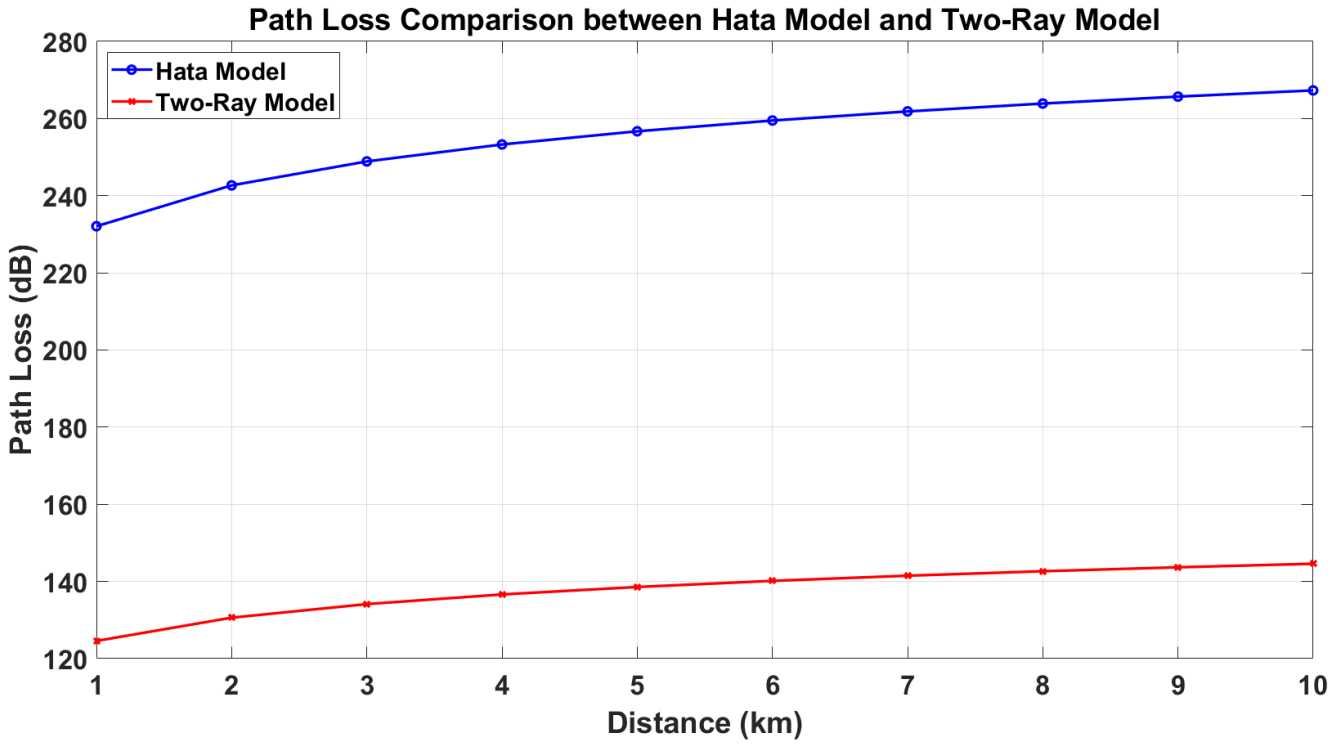
Compare the path loss estimated using Two-ray and Hata Models.
Use the following values:

i. Frequency of operation f = 900 MHz
ii. hte = 30m, hre = 1.5m
iii. Distance = 1:1:10 km
iv. Consider urban environment

Code:

```
clc
clear all
close all

f = 900;
ht = 30;
hr = 1.5;
d = 1:1:10;
d_meters = d * 1000;

% Hata Model Path Loss Calculation (Urban)
a_hr = (1.1*log10(f) - 0.7)*hr - (1.56*log10(f) - 0.8);
path_loss_hata = 69.55 + 26.16*log10(f) - 13.82*log10(ht) - a_hr + (44.9 -
6.55*log10(ht))*log10(d_meters);

% Two-Ray Model Path Loss Calculation
c = 3e8;
lambda = c / (f * 1e6);
path_loss_two_ray = (4 * pi * ht * hr * d_meters / lambda).^2;
path_loss_two_ray_dB = 10 * log10(path_loss_two_ray);


figure;
plot(d, path_loss_hata, '-o', 'DisplayName', 'Hata Model', 'LineWidth', 2,
'Color','blue');
hold on;
plot(d, path_loss_two_ray_dB, '-x', 'DisplayName', 'Two-Ray Model', 'LineWidth',
2, 'Color','red');
grid on;
xlabel('Distance (km)');
ylabel('Path Loss (dB)');
title('Path Loss Comparison between Hata Model and Two-Ray Model');
legend('Location', 'northwest');
set(gca,'FontSize',20,'FontWeight','bold');
```

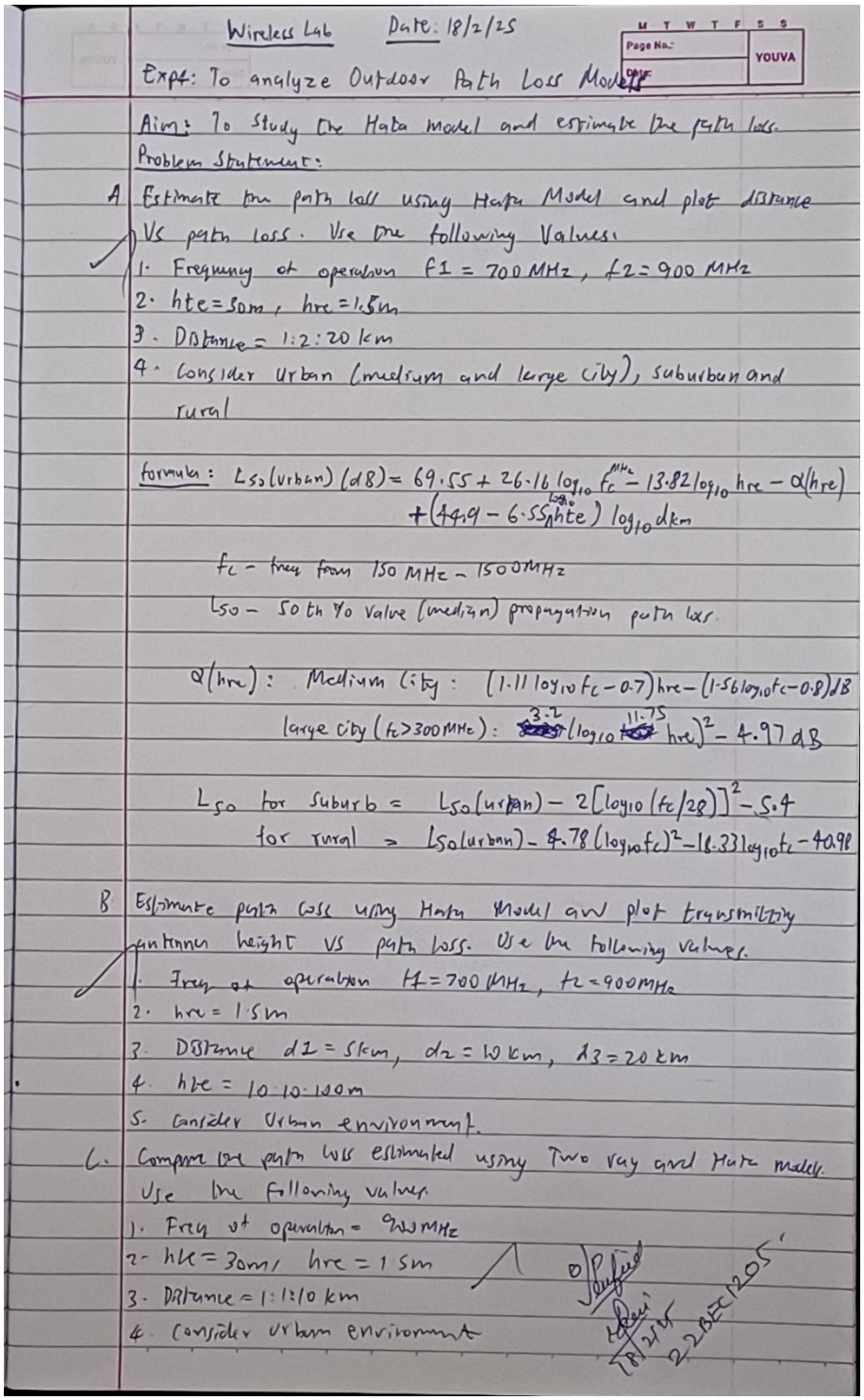
Output:



Inference:

Path loss for 2 Ray Model is comparatively less as compared to the Hata model for same distance.

Output Verification:



Wireless Lab Date: 18/2/25

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Expt: To analyze Outdoor Path Loss Models

Aim: To study the Hata model and estimate the path loss.

Problem Statement:

A Estimate the path loss using Hata Model and plot distance Vs path loss. Use the following values:

1. Frequency of operation f1 = 700 MHz, f2 = 900 MHz
2. hte = 50m, hre = 1.5m
3. Distance = 1:2:20 km
4. Consider Urban (medium and large city), suburban and rural

formula: $L_{50}(urban)(dB) = 69.55 + 26.16 \log_{10} f_c^{MHz} - 13.82 \log_{10} h_{re} - a(h_{re}) + (44.9 - 6.55 \log_{10} h_{te}) \log_{10} d_{km}$

f_c - freq from 150 MHz - 1500 MHz

L_{50} - 50th % value (median) propagation path loss.

$a(h_{re})$: Medium city: $(1.11 \log_{10} f_c - 0.7) h_{re} - (1.56 \log_{10} f_c - 0.8)$ dB

large city ($f_c > 300$ MHz): $3.2 (\log_{10} 11.75 h_{re})^2 - 4.97$ dB

L_{50} for Suburb = $L_{50}(urban) - 2[\log_{10}(f_c/28)]^2 - 5.4$

for rural = $L_{50}(urban) - 4.78 (\log_{10} f_c)^2 - 18.33 \log_{10} f_c - 40.98$

B Estimate path loss using Hata Model and plot transmitting antenna height vs path loss. Use the following values.

1. Freq of operation f1 = 700 MHz, f2 = 900 MHz
2. hre = 1.5m
3. Distance d1 = 5km, d2 = 10 km, d3 = 20 km
4. hte = 10-10-100m
5. Consider Urban environment.

C. Compare the path loss estimated using Two ray and Hata models. Use the following values.

1. Freq of operation = 900 MHz
2. hte = 30m, hre = 1.5m
3. Distance = 1:1:10 km
4. Consider urban environment

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Observation and Result:

Hence, the graphs of path loss with respect to distance and antenna height were plotted and observed for the Hata model. The Hata model was also compared with the Two Ray propagation model to observe the graph of path loss vs distance.