MWC Experiment 10

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BE EXTC A
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Aim:

To implement and simulate Okumura and Hata models using MATLAB

Theory:

1. OKUMURA MODEL

1.1 Origin and Background

1. Developed by Yoshihisa Okumura and colleagues (Tokyo, Japan, 1968).
2. Based on extensive field measurements in urban, suburban, and open areas.
3. Fully empirical model — derived entirely from measurement data.
4. Used for prediction of large-scale signal strength over distances from 1 km to 100 km.

1.2 Frequency and Distance Range

- Frequency range: 150 MHz to 1920 MHz (valid up to about 3 GHz).
- Distance range: 1 km to 100 km.
- Base station antenna height: 30 m to 1000 m.
- Mobile station antenna height: 1 m to 10 m.

1.3 Basic Equation

L50(dB) = Lf + Amu(f, d) - G(ht) - G(hr) - Garea

where:
L50 = median path loss (dB)
Lf = free-space path loss (dB)
Amu = median attenuation relative to free-space (from Okumura curves)
G(ht) = base station antenna height gain factor (dB)
G(hr) = mobile antenna height gain factor (dB)
Garea = area correction factor (dB)

1.4 Free-Space Path Loss

Lf = 32.44 + 20*log10(f) + 20*log10(d)

where f is in MHz and d is in km.

1.5 Antenna Height Gain Factors

G(ht) = 20*log10(ht / 200)

G(hr) = 10*log10(hr / 3)

1.6 Area Correction Factor (Typical)

Environment	Garea (dB)
Urban	0
Suburban	5 – 10
Open	10 – 15

1.7 Key Features

1. Derived from real-world measurements.
2. Provides accurate predictions for urban environments.
3. Includes terrain correction factors through empirical curves.
4. Lacks a closed-form analytical expression (graph-based).
5. Complex for automation and computation.

1.8 Limitations

1. Graphical nature makes it inconvenient for direct computation.
2. Valid primarily for the environments in which measurements were taken.
3. Requires interpolation from charts for attenuation values.

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2. HATA MODEL

2.1 Origin and Background

1. Developed by M. Hata in 1980.
2. Analytical formulation of Okumura's empirical data.
3. Provides a closed-form equation suitable for computer implementation.
4. Applicable to macro-cellular systems operating in the VHF and UHF bands.

2.2 Frequency and Distance Range

- Frequency range: 150 MHz to 1500 MHz.
- Distance range: 1 km to 20 km.
- Base station antenna height: 30 m to 200 m.

- Mobile station antenna height: 1 m to 10 m.

2.3 Hata Model Equations

(a) Urban Areas

L50(urban) = 69.55 + 26.16*log10(f) - 13.82*log10(ht)

- a(hr) + (44.9 - 6.55*log10(ht))*log10(d)

(b) Mobile Antenna Height Correction Factor a(hr)

For small to medium-sized cities:

a(hr) = (1.1*log10(f) - 0.7)*hr - (1.56*log10(f) - 0.8)

For large cities:

if f <= 300 MHz:

a(hr) = 8.29*(log10(1.54*hr))^2 - 1.1

else:

a(hr) = 3.2*(log10(11.75*hr))^2 - 4.97

(c) Suburban Areas

L50(suburban) = L50(urban) - 2*(log10(f/28))^2 - 5.4

(d) Open Rural Areas

L50(open) = L50(urban) - 4.78*(log10(f))^2 + 18.33*log10(f) - 40.94

2.4 Features

1. Analytical model — suitable for computer implementation.
2. Simpler and faster than Okumura model.
3. Provides reasonable accuracy for frequencies up to 1500 MHz.
4. Adaptable to urban, suburban, and open areas via correction terms.

2.5 Limitations

1. Valid only up to 1500 MHz (extended by COST-231 Hata for higher bands).
2. Not suitable for microcells (distance < 1 km).
3. Limited to relatively flat terrain; does not account for hills or clutter explicitly.

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3. COST-231 HATA EXTENSION

To extend Hata’s model up to 2000 MHz (GSM/UMTS bands):

L50(urban) = 46.3 + 33.9*log10(f) - 13.82*log10(ht)

- a(hr) + (44.9 - 6.55*log10(ht))*log10(d) + C

where
C = 3 dB for metropolitan areas
C = 0 dB for medium-sized cities and suburban areas

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4. COMPARISON SUMMARY

Parameter	**Okumura Model**	**Hata Model**
Basis	Empirical (measured curves)	Analytical (derived from Okumura)
Frequency range	150–1920 MHz	150–1500 MHz
Distance range	1–100 km	1–20 km
Base station height	30–1000 m	30–200 m
Mobile antenna height	1–10 m	1–10 m
Terrain effects	Explicit via curves	Implicit via correction terms
Computation	Graphical, manual	Analytical, computer-friendly
Accuracy	Very high in urban areas	High, slightly lower than Okumura

Code and Results:

```
% pathloss_model_selector.m

% Determine whether to use Okumura or Hata model based on user inputs

% and compute Hata (Okumura–Hata) path loss when applicable.


clear; clc; close all;


fprintf('=== Path Loss Model Selector ===\n');


%% ====== User Inputs ======

f = input('Enter frequency (MHz): ');

hte = input('Enter transmitter (base station) height (m): ');

hre = input('Enter receiver (mobile) height (m): ');

d = input('Enter distance between Tx and Rx (km): ');
```

```
fprintf('\nEnvironment options: urban | suburban | rural\n');
environment = input('Enter environment type: ', 's');

fprintf('\nCity size options: small | medium | large\n');
city_size = input('Enter city size: ', 's');

use_hata_as_fallback = true; % always compute Hata if Okumura is recommended

%% ====== Applicability ranges ======
hata_f_min = 150;    hata_f_max = 1500;    % MHz
hata_d_max = 20;     % km
okumura_f_max = 2000; % MHz
okumura_d_max = 100;  % km

%% ====== Decision logic ======
use_hata = false;
use_okumura = false;
note = '';

if f >= hata_f_min && f <= hata_f_max && d <= hata_d_max && hte >= 30 && hte <= 200 && hre >= 1 && hre <= 10
    use_hata = true;
    note = 'Hata (Okumura–Hata) model is applicable.';
elseif f >= hata_f_min && f <= okumura_f_max && d <= okumura_d_max
    use_okumura = true;
    note = 'Okumura model recommended (outside Hata range).';
else
    note = 'Neither model fits well; consider COST-231, Longley-Rice, or ITU models.';
end

%% ====== Display decision ======
```

```
fprintf('\n--- Model Decision ---\n');
fprintf('Frequency: %.1f MHz | Tx: %.1f m | Rx: %.1f m | Distance: %.2f km | Env: %s\n', ...
    f, hte, hre, d, environment);
if use_hata
  fprintf('Selected Model: Hata (Okumura–Hata)\n');
elseif use_okumura
  fprintf('Selected Model: Okumura (original)\n');
else
  fprintf('Selected Model: None (parameters outside typical range)\n');
end
fprintf('Note: %s\n\n', note);

%% ====== Hata path loss computation ======
if use_hata || (use_okumura && use_hata_as_fallback)
  L_hata = computeHataLoss(f, hte, hre, d, environment, city_size);
  fprintf('--- Hata Path Loss Estimate ---\n');
  fprintf('Estimated Path Loss: %.2f dB\n', L_hata);
end

if use_okumura
  fprintf('\n--- Okumura Notes ---\n');
  fprintf(['Okumura model requires empirical median-attenuation curves (Amu) and area correction factors.\n'
...
      'Fallback Hata estimate shown above. For precise results, provide Amu data or use COST-231.\n']);
end

fprintf('\n=== End ===\n');

%% ====== Hata Path Loss Function ======
function L = computeHataLoss(f, hte, hre, d, env, city_size)
  % f in MHz, hte/hre in m, d in km
  % env = 'urban' | 'suburban' | 'rural'
```

```
% city_size = 'small' | 'medium' | 'large'

if d <= 0
    error('Distance must be > 0 km');
end

% Mobile antenna correction factor
if strcmpi(city_size,'large')
    if f <= 200
        a_hre = 8.29*(log10(1.54*hre))^2 - 1.1;
    else
        a_hre = 3.2*(log10(11.75*hre))^2 - 4.97;
    end
else
    a_hre = (1.1*log10(f) - 0.7)*hre - (1.56*log10(f) - 0.8);
end

% Hata Urban Path Loss
L_urban = 69.55 + 26.16*log10(f) - 13.82*log10(hte) - a_hre ...
          + (44.9 - 6.55*log10(hte))*log10(d);

switch lower(env)
    case 'urban'
        L = L_urban;
    case 'suburban'
        L = L_urban - 2*(log10(f/28))^2 - 5.4;
    case 'rural'
        L = L_urban - 4.78*(log10(f))^2 + 18.33*log10(f) - 40.94;
    otherwise
        warning('Unknown environment "%s". Using urban default.', env);
        L = L_urban;
```

```
  end
end
```

okumurahata.m

Command Window

```
=== Path Loss Model Selector ===
Enter frequency (MHz): 900
Enter transmitter (base station) height (m): 50
Enter receiver (mobile) height (m): 3
Enter distance between Tx and Rx (km): 5

Environment options: urban | suburban | rural
Enter environment type: urban

City size options: small | medium | large
Enter city size: medium

--- Model Decision ---
Frequency: 900.0 MHz | Tx: 50.0 m | Rx: 3.0 m | Distance: 5.00 km | Env: urban
Selected Model: Hata (Okumura-Hata)
Note: Hata (Okumura-Hata) model is applicable.

--- Hata Path Loss Estimate ---
Estimated Path Loss: 143.12 dB

=== End ===
>>
```

okumurahata.m

Command Window

```
=== Path Loss Model Selector ===
Enter frequency (MHz): 1800
Enter transmitter (base station) height (m): 250
Enter receiver (mobile) height (m): 8
Enter distance between Tx and Rx (km): 50

Environment options: urban | suburban | rural
Enter environment type: suburban

City size options: small | medium | large
Enter city size: large

--- Model Decision ---
Frequency: 1800.0 MHz | Tx: 250.0 m | Rx: 8.0 m | Distance: 50.00 km | Env: suburban
Selected Model: Okumura (original)
Note: Okumura model recommended (outside Hata range).

--- Hata Path Loss Estimate ---
Estimated Path Loss: 151.74 dB

--- Okumura Notes ---
Okumura model requires empirical median-attenuation curves (Amu) and area correction factors.
Fallback Hata estimate shown above. For precise results, provide Amu data or use COST-231.

=== End ===
>>
```

Conclusion:

1. The code automatically selects between Hata (Okumura–Hata) and Okumura models based on frequency, distance, and antenna heights, with Hata used for formula-based calculations within its validity range.

2. Environmental type (urban, suburban, rural) and city size influence path loss via correction factors, reflecting realistic propagation conditions.
3. Okumura is recommended for broader frequency/distance ranges, but the code provides a Hata-based fallback for convenience and computational simplicity.
4. Robust error handling ensures invalid inputs or unknown environments are managed gracefully, maintaining reliable outputs.