Department of Electronic and Telecommunication Engineering

University of Moratuwa, Sri Lanka

EN 2053 - Communication Systems and Networks

Assignment on Wireless Communication

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Contents

1 Modeling the RF propagation Model Using Matlab

1.1 Relationship between Free Space Path Loss and Frequency

Consider following meanings for the parameters

P_{RX} = Received Power at the Receiving Antenna
P_{TX} = Transmitted Power at the Transmitting Antenna
f = Frequency of the wave in Hz
f_{GHz} = Frequency of the wave in GHz
d = Distance between the antennas in m
d_{km} = Distance between the antennas in km
G_{TX} = Directive gain of the Transmitter
G_{RX} = Directive gain of the Receiver
c = Velocity of the electromagnetic waves in a vacuum

The relationship between above parameters can be given as follows

$$P_{RX} = P_{TX}.\frac{c^2}{(4\pi.f.d)^2}.G_{TX}.G_{RX}$$

From the above equation, free space path loss, say L

$$L = \frac{(4\pi.f.d)^2}{c^2}$$

By considering $10.log_{10}()$ in both sides, Free Space Path Loss in dB, say L_{dB}

$$\begin{aligned}
10.\log_{10}(L) &= 10.\log_{10}(\frac{(4\pi.f.d)^2}{c^2}) \\
L_{dB} &= 10.\log_{10}((4\pi.f.d)^2) - 10.\log_{10}(c^2) \\
&= 20.\log_{10}(4\pi.f.d) - 20.\log_{10}(c) \\
&= 20.\log_{10}(4\pi) - 20.\log_{10}(c) + 20.\log_{10}(f) + 20.\log_{10}(d) \\
&= 20.\log_{10}(\frac{4\pi}{c}) + 20.\log_{10}(f) + 20.\log_{10}(d) \\
&= -147.5522168 + 20.\log_{10}(f_{GHz}.10^9) + 20.\log_{10}(d_{km}.10^3) \\
&= -147.5522168 + 20.\log_{10}(10^9) + 20.\log_{10}(f_{GHz}) + 20.\log_{10}(10^3) + 20.\log_{10}(d_{km}) \\
&= -147.5522168 + 180 + 20.\log_{10}(f_{GHz}) + 60 + 20.\log_{10}(d_{km}) \\
&= -147.5522168 + 240 + 20.\log_{10}(f_{GHz}) + 20.\log_{10}(d_{km}) \\
&= +92.44778322 + 20.\log_{10}(f_{GHz}) + 20.\log_{10}(d_{km})
\end{aligned}$$

Since transmitter and receiver are located at distance of 10km apart, by substituting $d_{km} = 10$.

Free Space Path Loss in dB, L_{dB} as a function of frequency in Giga Hertz

$$L_{dB}(f_{GHz}) = +112.44778322 + 20.\log_{10}(f_{GHz})$$

Note : Axes of the following plots are given in the logarithmic scale and range of frequency was chosen from 50 GHz to 1000 GHz since some of the ITU-R models are only defined in the 10 GHz-1000 GHz range.

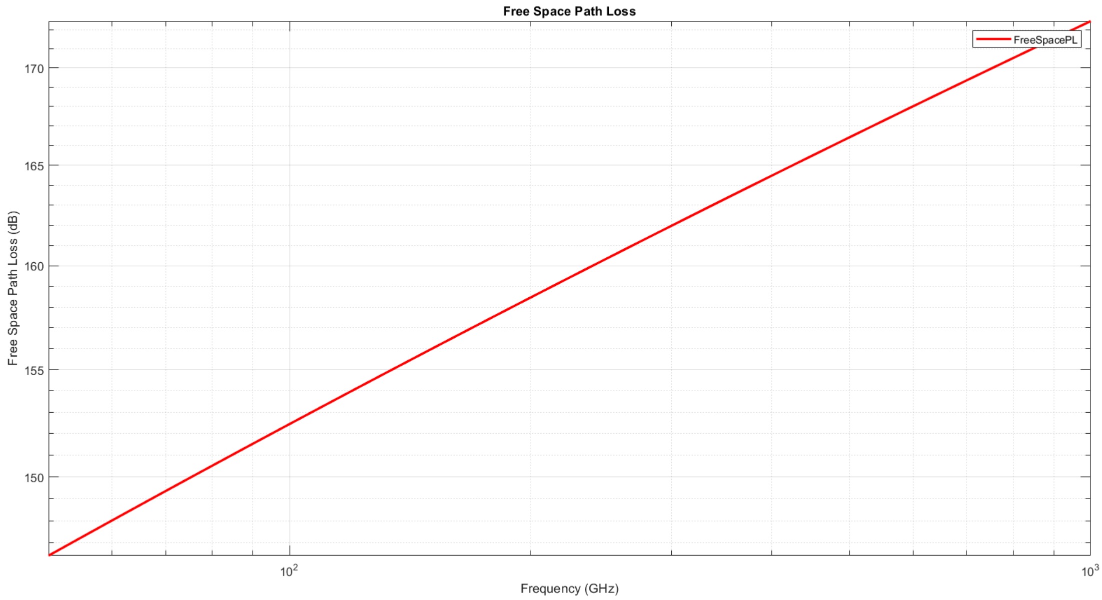

Figure 1: Relationship between Free Space Path Loss and Frequency

1.2 Rain attenuation, Fog attenuation and Atmospheric gas attenuation with Frequency

Note : For the generation of following plots three of the Matlab built-in functions, namely ***rainpl()**[1]*, ***gaspl()**[1]*, ***fogpl()**[1] which are developed according to the ITU-R P Series recommendations were used and links for their documentations are given at the Reference section.*

1.2.1 Rain attenuation - Recommendation ITU-R P.838-3, 2005[3]

The following plot shows how losses due to rain varies with frequency. The plot assumes the followings in addition to the provided information in the Task 1.

Elevation angle of the propagation path	= 0
Polarization tilt angle of the signal	= 0

In general, horizontal polarization represents the worse case for propagation loss due to rain.

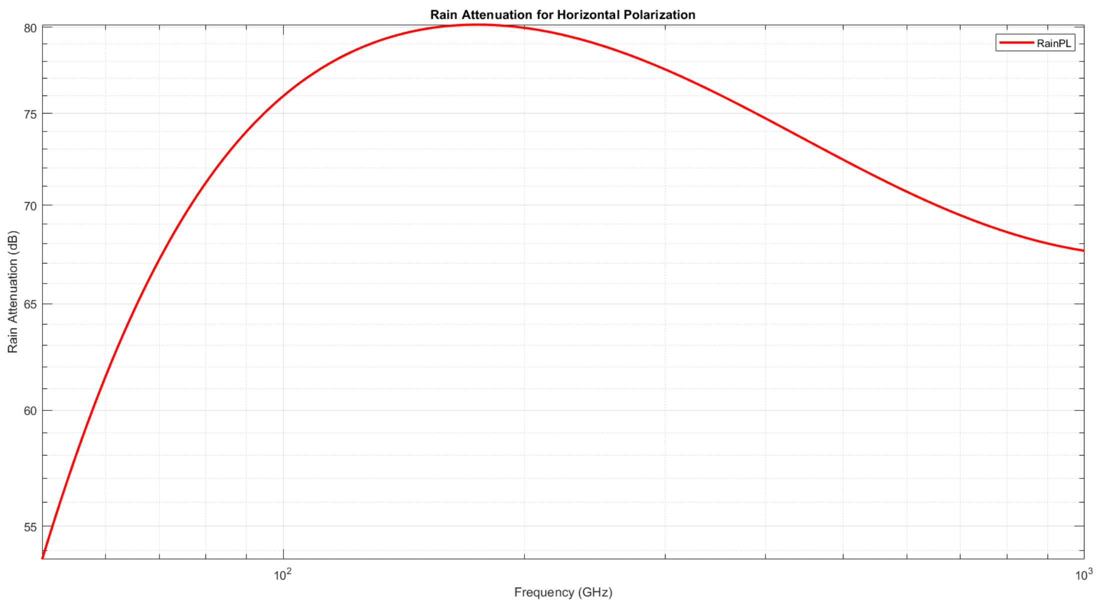

Figure 2: Relationship between Rain attenuation and Frequency

1.2.2 Fog attenuation - Recommendation ITU-R P.840-3, 2013[4]

The following plot shows how losses due to fog/cloud varies with frequency. The plot assumes the following provided information in the Task 1.

Ambient Temperature in Celsius	$= 31$
Liquid Water Density in g/m^3	$= 0.5$

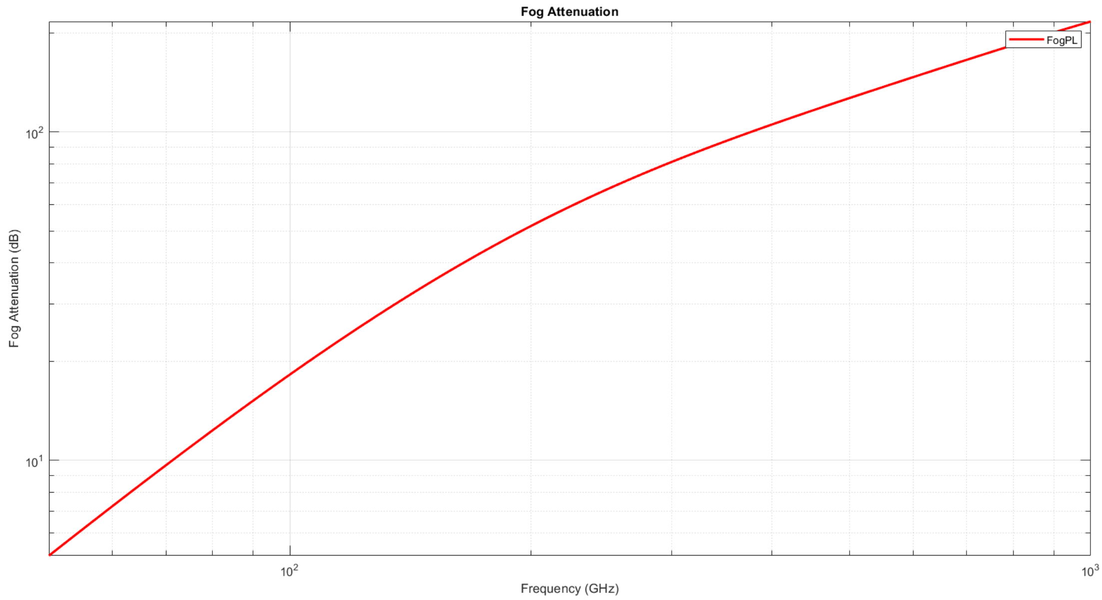

Figure 3: Relationship between Fog attenuation and Frequency

1.2.3 Atmospheric gas attenuation - Recommendation ITU-R P.676-10, 2013[2]

The plot below shows how the propagation loss due to atmospheric gases varies with the frequency. The plot assumes the followings in addition to the provided information in the Task 1.

Dry air pressure in Pa	$= 101325$
Water Vapor Density in g/m^3	$= 30.4$

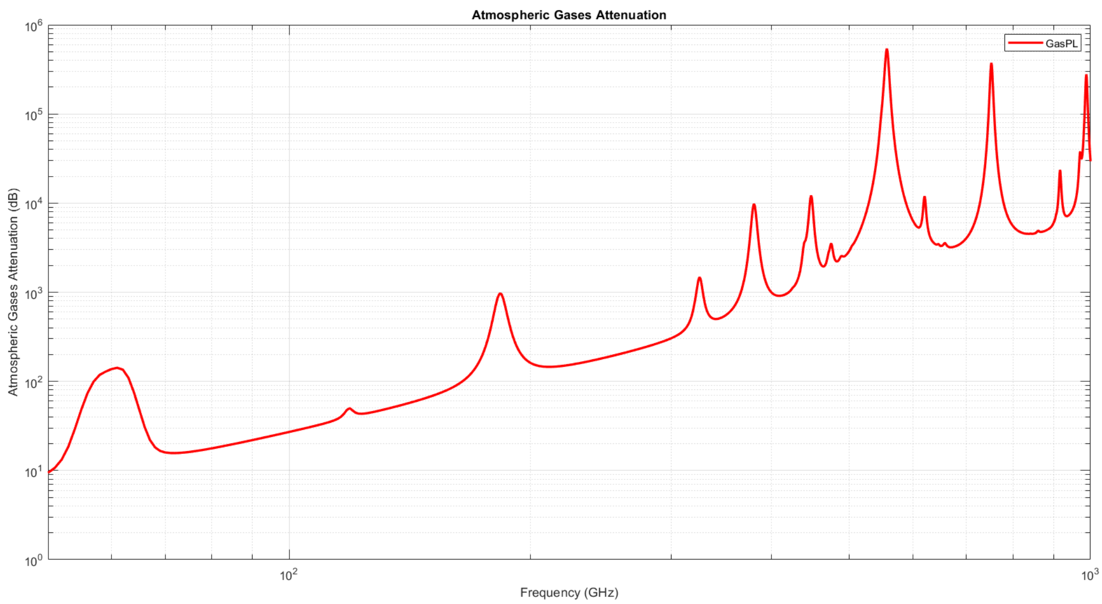

Figure 4: Relationship between Atmospheric gas attenuation and Frequency

1.3 Total Path Loss with Frequency

Note : Range of frequency was chosen from 50 GHz to 1000 GHz since some of the ITU-R models are only defined in 10 GHz - 1000 GHz range.

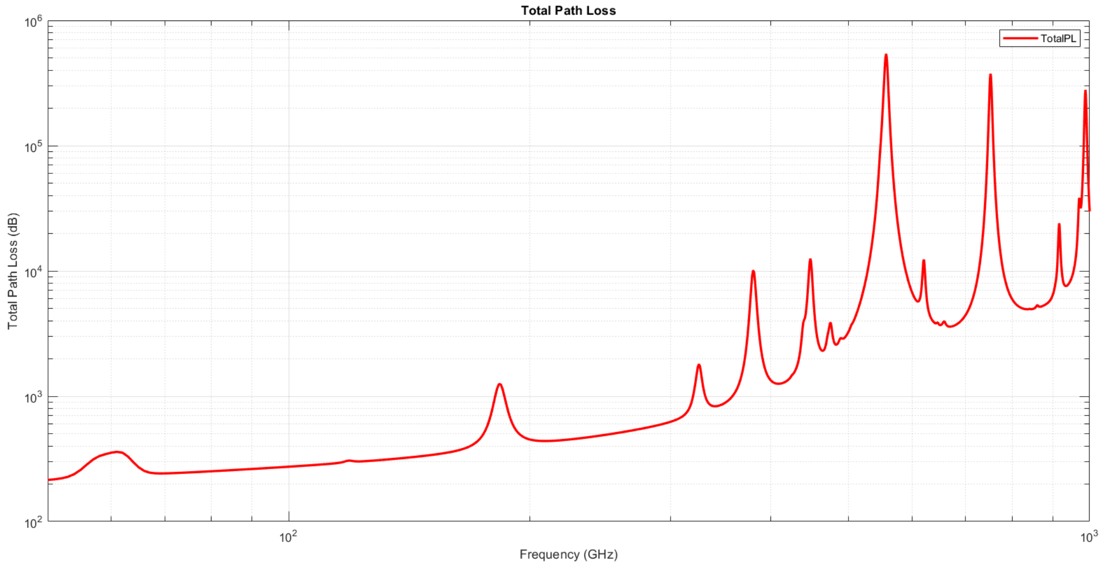

Figure 5: Relationship between Total Path Loss and Frequency

By inspecting the figure we can conclude that the minimum propagation loss is given at the frequency of 50 GHz in the given range. Therefore from this point onward, for the calculations it will be the frequency for transmission.

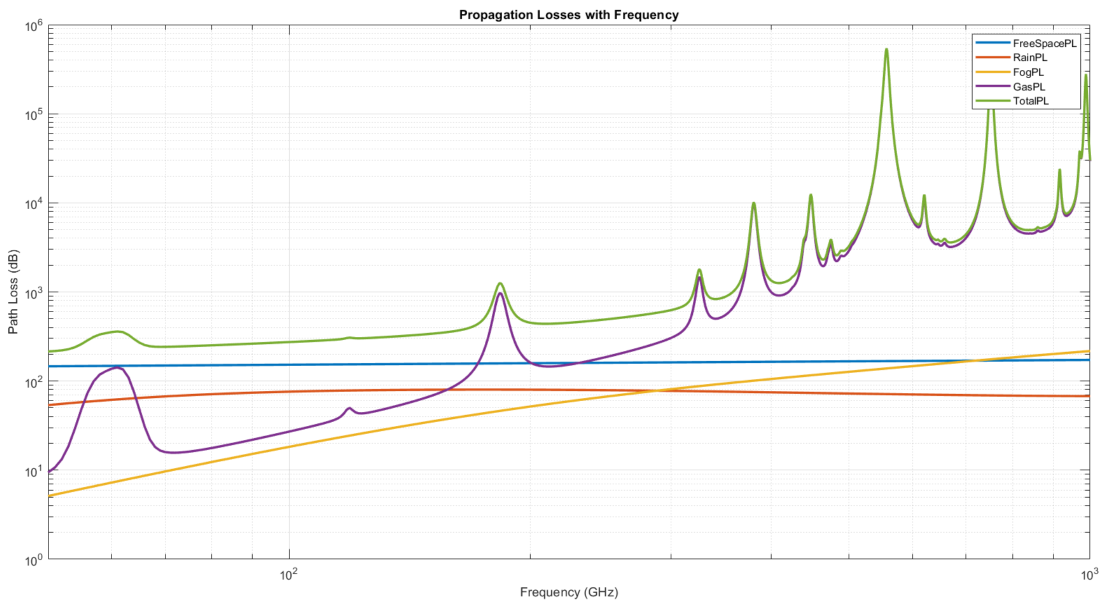

Figure 6: Relationship between Various Path Losses and Frequency - All in One

1.4 Variation of the Signal Power with the Distance

Parameters For the propagation model

Chosen transmission frequency	50 GHz
Transmission power	50 kW or 47 dB
Cable loss at Transmitter	3 dB
Transmitter Gain	30 dB
Receiver Gain	24.77 dB
Cable loss at Receiver	4 dB
Total Path Loss	Varies with Distance

According to above values, Let's calculate the Power of the signal when leaving the Transmission antenna, say $P_{dB}(0\ km)$,

$$\begin{aligned} P_{dB}(0\ km) &= Transmission\ power - Cable\ loss\ at\ Transmitter + Transmitter\ Gain \\ &= 47 - 3 + 30 \\ &= 74\ dB \end{aligned}$$

Free Space Path Loss in dB, L_{dB} as a function of distance in kilo meters. By substituting f_{GHz} = 50 to the equation derived in part 1.

$$\begin{aligned} L_{dB}(d_{km}) &= +92.44778322 + 20.\log_{10}(50) + 20.\log_{10}(d_{km}) \\ &= +92.44778322 + 33.97940009 + 20.\log_{10}(d_{km}) \\ &= +126.4271833 + 20.\log_{10}(d_{km}) \end{aligned}$$

Therefore,

$$Total\ Path\ Loss = L_{dB}(d_{km}) + Rain\ Attenuation + Fog\ Attenuation + Atmospheric\ Gas\ Attenuation$$

Therefore the Signal Power when reaching the Receiving Antenna at d_{km} distance,

$$P_{dB}(d_{km}) = 74\ dB - Total\ Path\ Loss$$

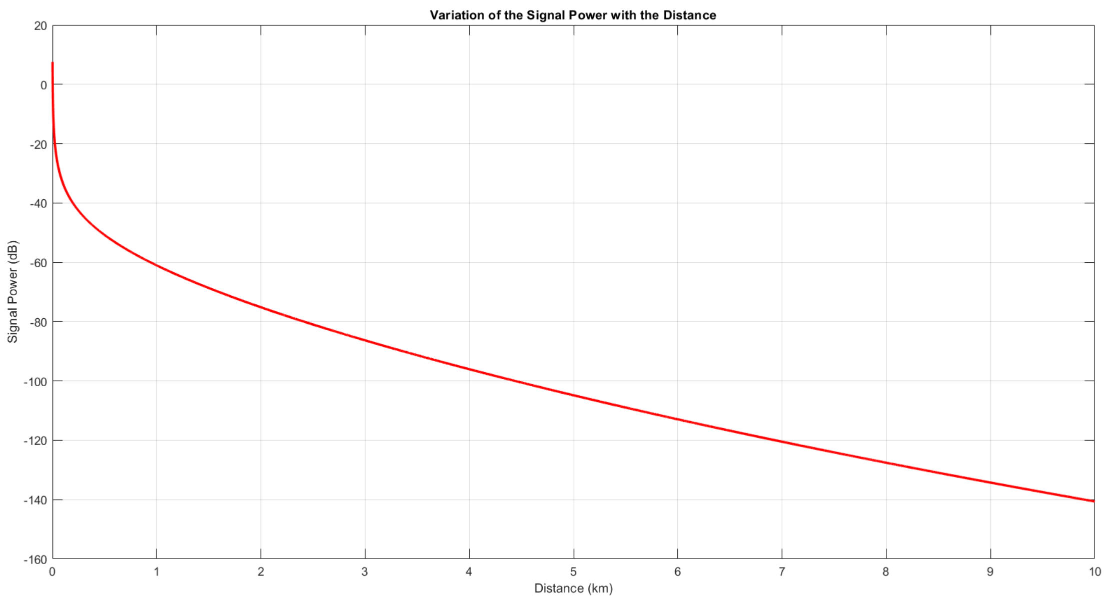

Figure 7: Variation of the Signal Power with the Distance

1.5 Transmitting a voice signal over a noisy channel using the above Transmission frequency and the Propagation model.

1.6 Codes and Models for Task 1

```
%% Initialization
clear; close all; clc
%% ========= Free Space Propagation Loss with Frequency =========

%Defining the frequency range in GigaHertz
f_GHz = 50:1000;
%Free Space Path Loss Model obtained through calculations
freeSpaceLoss1 = 112.44778322 + 20*log10(f_GHz);

% Plotting Data
plotCurve(freeSpaceLoss1, 'FreeSpacePL')

%% == Rain, Fog, Atmospheric Gases Attenuations with Frequency ==

freq = f_GHz*1e9;% Defining the frequency range in Hertz
range = 10e3;    % Distance between transmitter and receiver in m
rainrate = 20;   % Rain rate in mm/h
elev = 0;        % Elevation angle of the propagation path
tau = 0;         % Polarization tilt angle of the signal
temp = 31;       % Ambient Temperature in celcious
dens = 0.5;      % Liquid Water Density in g/m^3
rou = 30.4;      % Water Vapor Density in g/m^3
p =  101325;     % Atmospheric Pressure in Pa at sea level

% Calculating Attenuations
rainAttenuation = rainpl(range,freq,rainrate,elev,tau);
fogAttenuation = fogpl(range,freq,temp,dens);
gasAttenuation = gaspl(range,freq,temp, p, rou);

% Plotting Data
plotCurve(rainAttenuation, 'RainPL');
plotCurve(fogAttenuation, 'FogPL');
plotCurve(gasAttenuation, 'GasPL');

%% ============ Total Propagation Loss with Frequency ============

% Calculating Total Attenuation
Totalpathloss = freeSpaceLoss1 + rainAttenuation + ...
                                fogAttenuation +gasAttenuation;
% Plotting Data
plotCurve(Totalpathloss, 'TotalPL');

%% ======= Variation of the Signal Power with the Distance =======

distance = 0:10e3; % Distance between transmitter and receiver in m
freq = 50*1e9;     % Choosen frequency value in Hertz

% Calculating Attenuations with Distance
freeSpaceLoss2 = 126.4271833 + 20*log10(distance/(10e2));
rainAttenuation = rainpl(distance,freq,rainrate,elev,tau);
fogAttenuation = fogpl(distance,freq,temp,dens);
gasAttenuation = gaspl(distance,freq,temp, p, rou);

% Total Path Loss with Distancce
```

```
TotalLosswithDistance = freeSpaceLoss2' + rainAttenuation + ...
                                    fogAttenuation +gasAttenuation;

% Calculating the signal Power with the distance
signalPower =  74 - TotalLosswithDistance;

% Plotting Data
plot(distance/10e2, signalPower, 'r','LineWidth', 2);
grid on;
xlabel('Distance (km)');
ylabel('Signal Power (dB)');
title('Variation of the Signal Power with the Distance');
```

```
function [] = plotCurve(inputArg1,inputArg2)
% Function to plot the Curves

f_GHz = 50:1000;%Defining the frequency range in GigaHertz
figure;
loglog(f_GHz, inputArg1, 'r', 'LineWidth', 2);
grid on;
xlabel('Frequency (GHz)');

if strcmp(inputArg2, 'FreeSpacePL')
    ylabel('Free Space Path Loss (dB)');
    title('Free Space Path Loss');

elseif strcmp(inputArg2, 'RainPL')
     ylabel('Rain Attenuation (dB)');
     title('Rain Attenuation for Horizontal Polarization');

elseif strcmp(inputArg2, 'FogPL')
     ylabel('Fog Attenuation (dB)');
     title('Fog Attenuation');

elseif strcmp(inputArg2, 'GasPL')
     ylabel('Atmospheric Gases Attenuation (dB)');
     title('Atmospheric Gases Attenuation');

elseif strcmp(inputArg2, 'TotalPL')
     ylabel('Total Path Loss (dB)');
     title('Total Path Loss');
end

legend(inputArg2);
%saveas(gcf,strcat(inputArg2,'.png'));
fprintf('Program paused. Press enter to continue.\n');
pause;
end
```

2 Implementing a Simplified Version of the Dynamic Source Routing(DSR) Protocol in Ad Hoc Wireless Networks

2.1 Assumptions used in the implementation

- Transmission ranges of all the nodes is the same and hence bidirectional communication is possible between two neighboring nodes
- Therefore, the source route of the RREP(Route Reply) is replaced with source route of RREQ(Route Request) packet.
- Route maintenance found in original DSR protocol is skipped for simplicity.

2.2 Implementation of DSR in Python

2.3 Improving the Efficiency of Protocol by further Exploiting the Route Cache

2.4 Handling Disconnections During Transmission

2.5 Differences between DSR protocol and Distance Vector Routing protocol

Bibliography

[1] Modeling the Propagation of RF Signals - MATLAB & Simulink - MathWorks India.

[2] P.676 : Attenuation by atmospheric gases.

[3] P.838 : Specific attenuation model for rain for use in prediction methods.

[4] P.840 : Attenuation due to clouds and fog.