

Department of Electronic and Telecommunication Engineering

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EN 2053 - Communication Systems and Networks



Assignment on Wireless Communication

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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

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

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

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

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

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

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

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

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

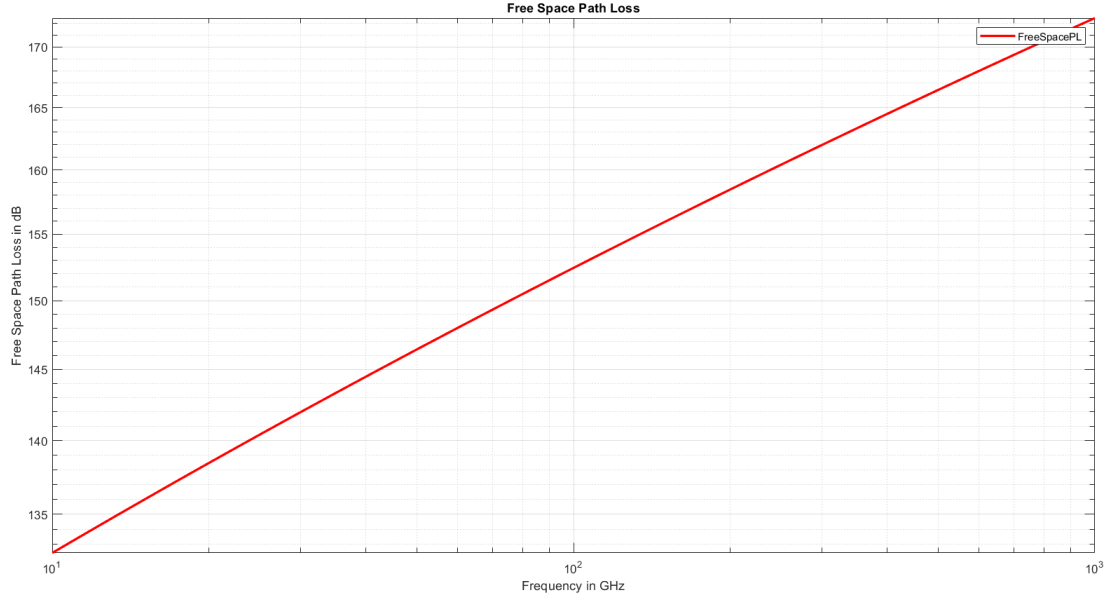


Figure 1: Relationship between Free Space Path Loss and Frequency

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()**, **gaspl()**, **fogpl()** 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

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.

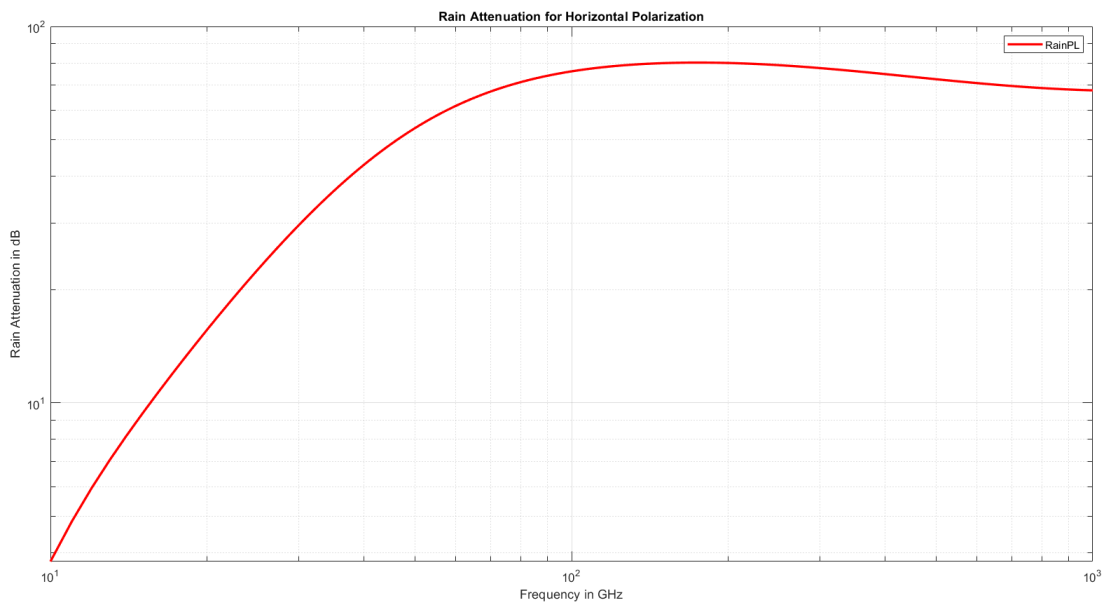


Figure 2: Relationship between Rain attenuation and Frequency

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

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

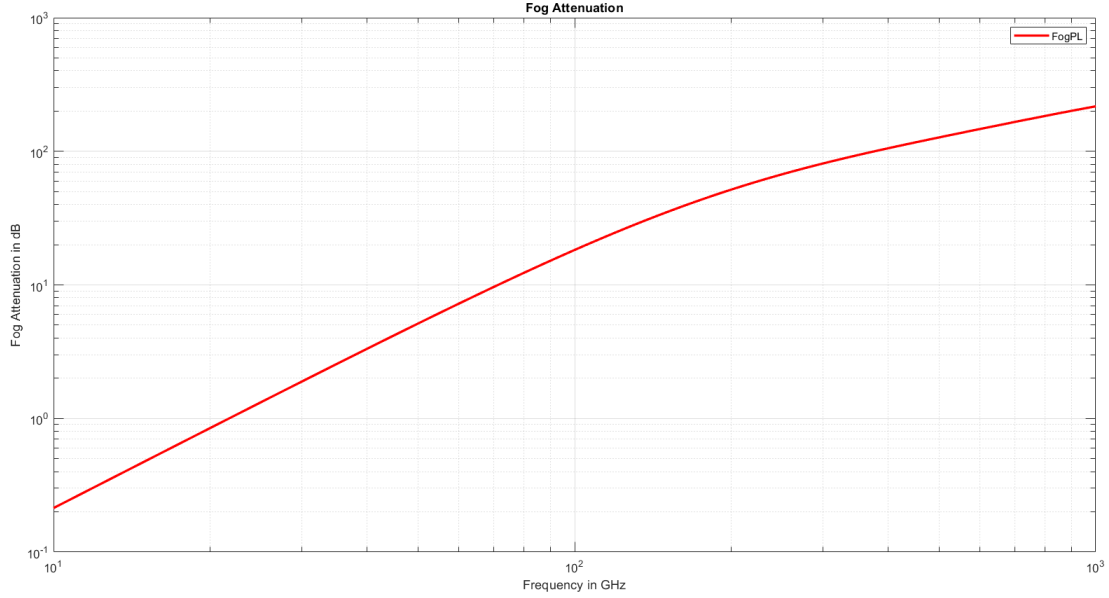


Figure 3: Relationship between Fog attenuation and Frequency

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

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

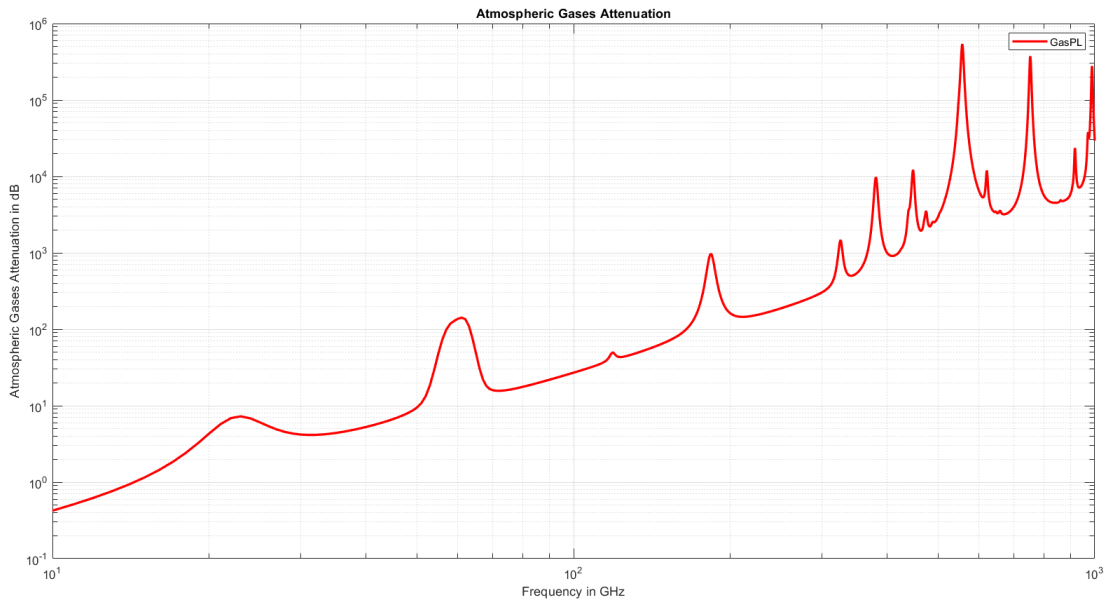


Figure 4: Relationship between Atmospheric gas attenuation and Frequency

1.3 Total Path Loss with Frequency

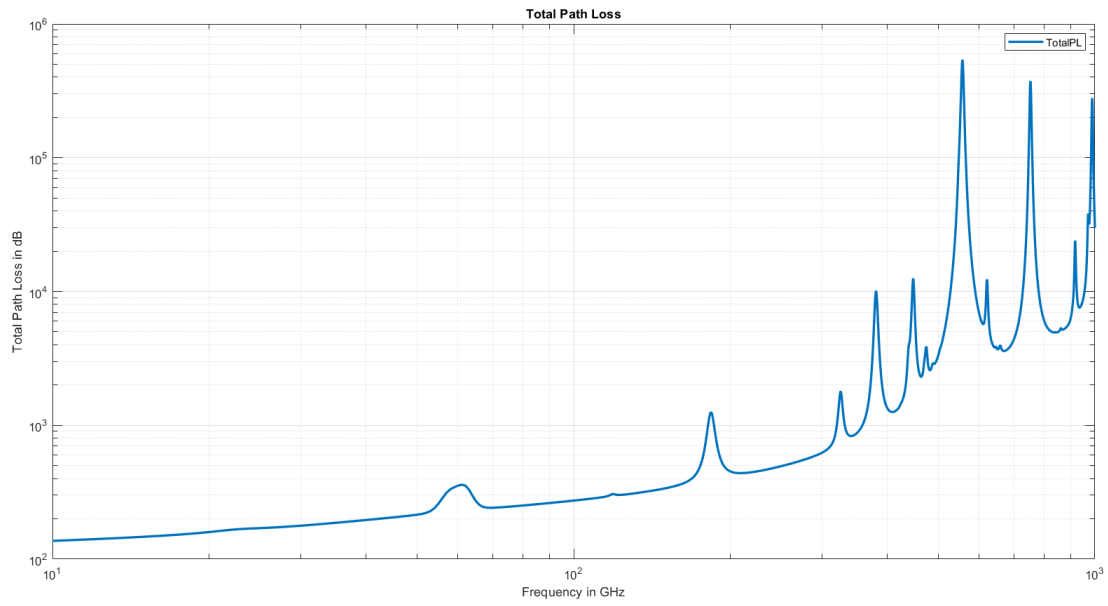


Figure 5: Relationship between Total Path Loss and Frequency

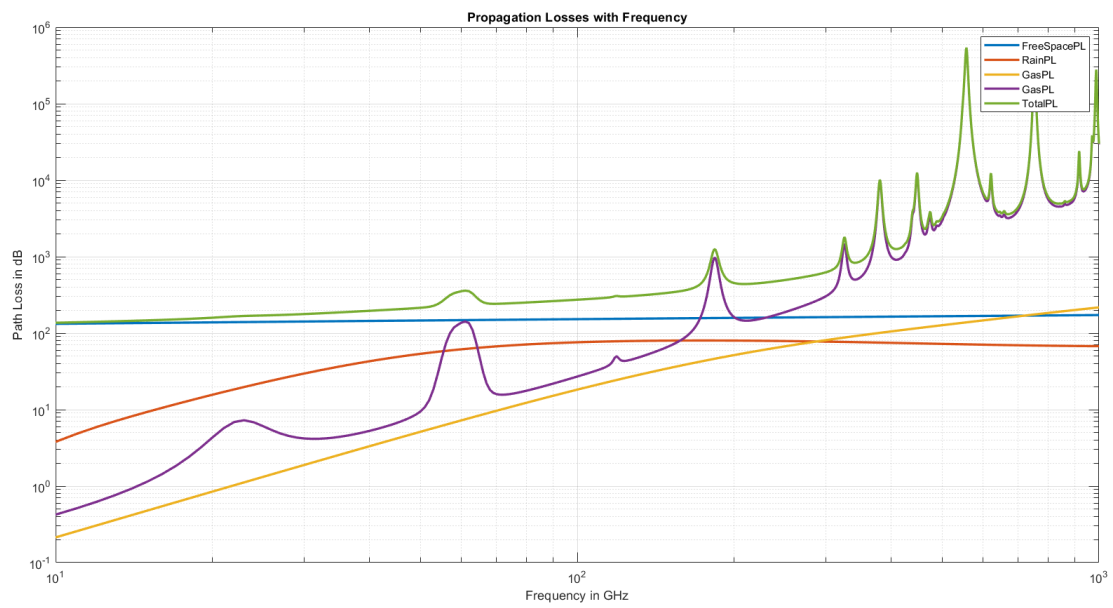


Figure 6: Relationship between Various Path Losses and Frequency

1.4 Codes and Models for Task 1

```
1 %% Initialization
2 clear; close all; clc
3 %% === Free Space Path Loss with Frequency ===
4
5 %Defining the frequency range in GigaHertz
6 f_GHz = 10:1000;
7 %Free Space Path Loss Model obtained from calculations
8 freeSpaceLoss = 112.44778322 + 20*log10(f_GHz);
9
10 % Plotting Data
11 figure;
12 loglog(f_GHz,freeSpaceLoss, 'LineWidth', 2);
13 grid on;
14 xlabel('Frequency in GHz');
15 ylabel('Free Space Path Loss in dB');
16 title('Free Space Path Loss');legend('FreeSpacePL');
17
18 fprintf('Program paused. Press enter to continue.\n');
19 pause;
20 %% === Rain Attenuation with Frequency ===
21
22 range = 10e3; % Distance between transmitter and receiver in m
23 rainrate = 20; % Rain rate in mm/h
24 elev = 0; % Elevation angle of the propagation path
25 tau = 0; % Polarization tilt angle of the signal
26
27 % Defining the frequency range in Hertz
28 freq = f_GHz*1e9;
29 % calculating Rain Attenuation
30 rainAttenuation = rainpl(range,freq,rainrate,elev,tau);
31
32 % Plotting Data
33 figure;
34 loglog(f_GHz,rainAttenuation, 'LineWidth', 2);
35 grid on;
36 xlabel('Frequency in GHz');
37 ylabel('Rain Attenuation in dB')
38 title('Rain Attenuation for Horizontal Polarization');
39 legend('RainPL');
40
41 fprintf('Program paused. Press enter to continue.\n');
42 pause;
43 %% === Fog Attenuation with Frequency ===
44
45 temp = 31; % Ambient Temperature in celcius
46 dens = 0.5; % Liquid Water Density in g/m^3
47
48 % calculating Fog Attenuation
49 fogAttenuation = fogpl(range,freq,temp,dens);
50
51 % Plotting Data
52 figure;
53 loglog(f_GHz,fogAttenuation, 'LineWidth', 2);
54 grid on;
```

```

55 xlabel('Frequency in GHz');
56 ylabel('Fog Attenuation in dB')
57 title('Fog Attenuation');legend('FogPL');
58
59 fprintf('Program paused. Press enter to continue.\n');
60 pause;
61 %% === Atmospheric Gases Attenuation with Frequency ===
62
63 rou = 30.4; % Water Vapor Density in g/m^3
64 p = 101325; % Atmospheric Pressure in Pa at sea level
65
66 % calculating Fog Attenuation
67 gasAttenuation = gaspl(range,freq,temp, p, rou);
68
69 % Plotting Data
70 figure;
71 loglog(f_GHz,gasAttenuation, 'LineWidth', 2);
72 grid on;
73 xlabel('Frequency in GHz');
74 ylabel('Atmospheric Gases Attenuation in dB')
75 title('Atmospheric Gases Attenuation');legend('GasPL');
76
77 fprintf('Program paused. Press enter to continue.\n');
78 pause;
79 %% ===== Total Path Loss with Frequency =====
80
81 % Calculating total Attenuation
82 Totalpathloss = freeSpaceLoss + rainAttenuation + ...
83 fogAttenuation +gasAttenuation;
84
85 % Plotting Data
86 figure;
87 loglog(f_GHz, Totalpathloss, 'LineWidth', 2);
88 grid on;
89 xlabel('Frequency in GHz');
90 ylabel('Total Path Loss in dB')
91 title('Total Path Loss'); legend('TotalPL')
92
93 fprintf('Program paused. Press enter to continue.\n');
94 pause;
95 %% ===== To view all losses on the same figure =====
96
97 figure;
98 loglog(f_GHz,freeSpaceLoss, 'LineWidth', 2);
99 hold on;
100 loglog(f_GHz,rainAttenuation, 'LineWidth', 2);
101 loglog(f_GHz,fogAttenuation, 'LineWidth', 2);
102 loglog(f_GHz,gasAttenuation, 'LineWidth', 2);
103 loglog(f_GHz, Totalpathloss, 'LineWidth', 2);
104 grid on;
105 xlabel('Frequency in GHz');
106 ylabel('Path Loss in dB')
107 title('Propagation Losses with Frequency')
108 legend('FreeSpacePL','RainPL','GasPL','GasPL','TotalPL');

```