

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}

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

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 50 GHz to 1000 GHz since some of the ITU-R models are only defined in the 10 GHz-1000 GHz range.

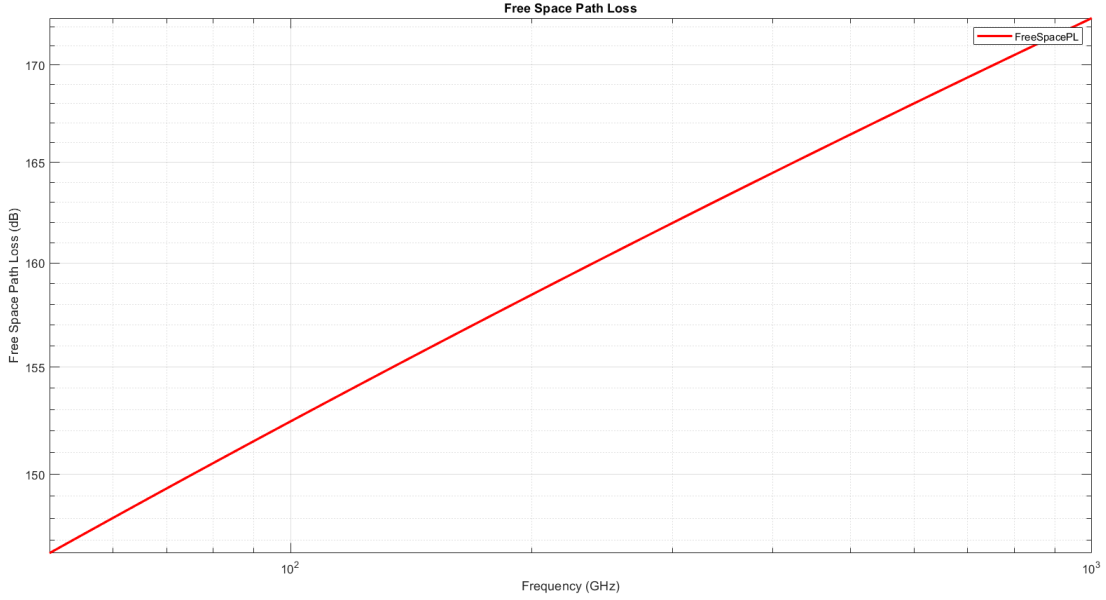


Figure 1: Relationship between Free Space Path Loss and Frequency

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.

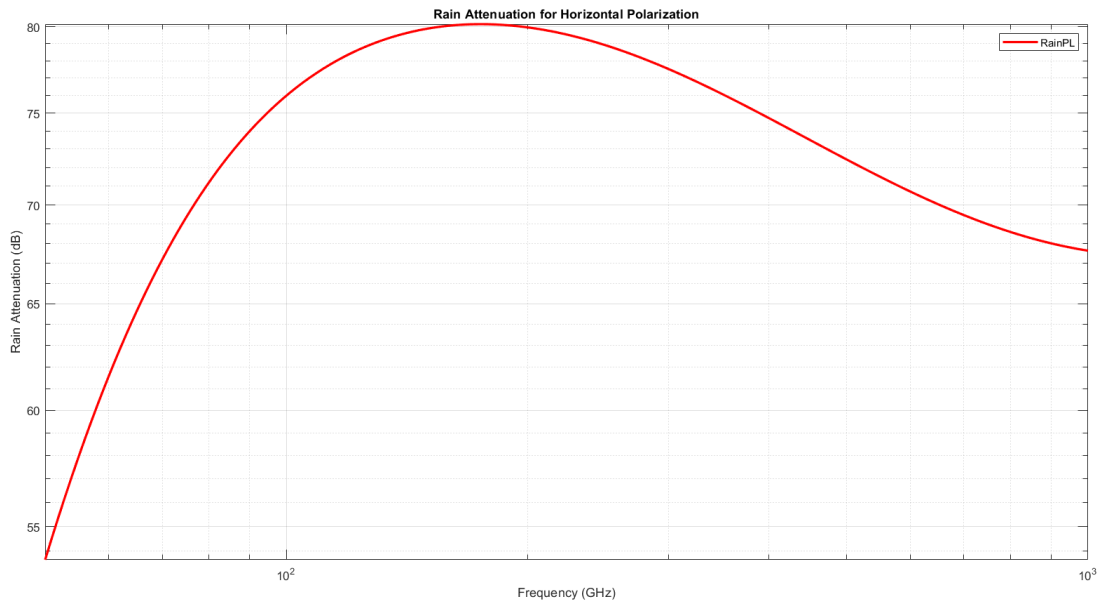


Figure 2: Relationship between Rain attenuation and Frequency

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

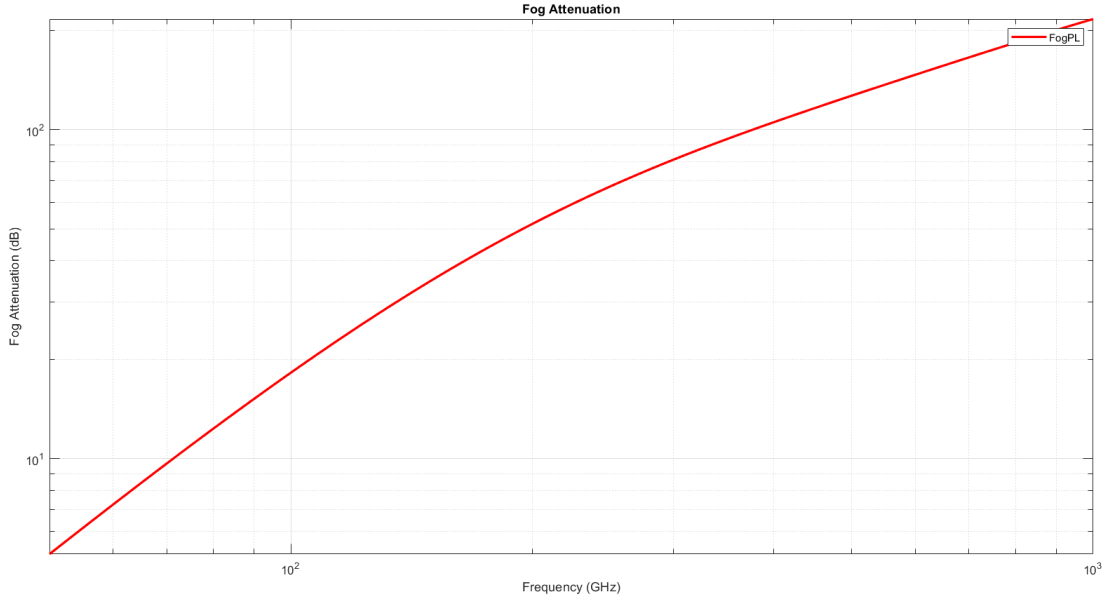


Figure 3: Relationship between Fog attenuation and Frequency

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

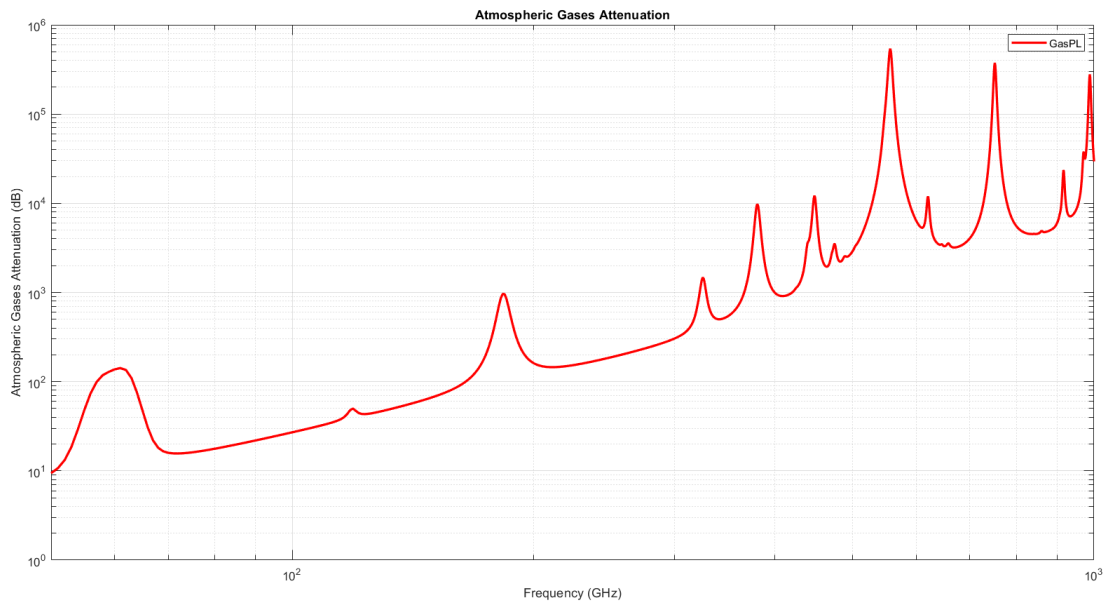


Figure 4: Relationship between Atmospheric gas attenuation and Frequency

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.

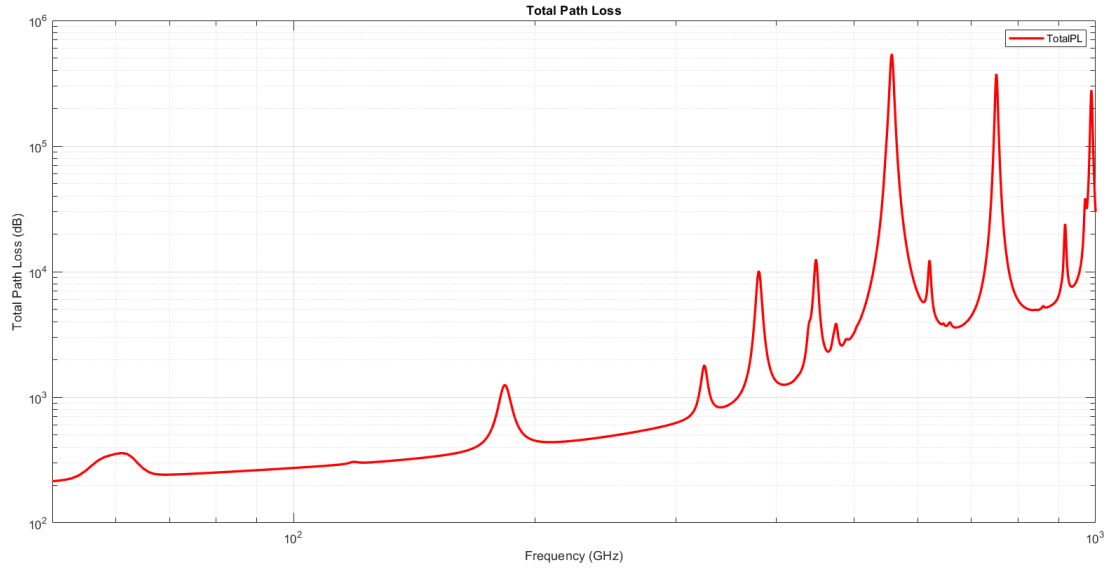


Figure 5: Relationship between Total Path Loss and Frequency

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.

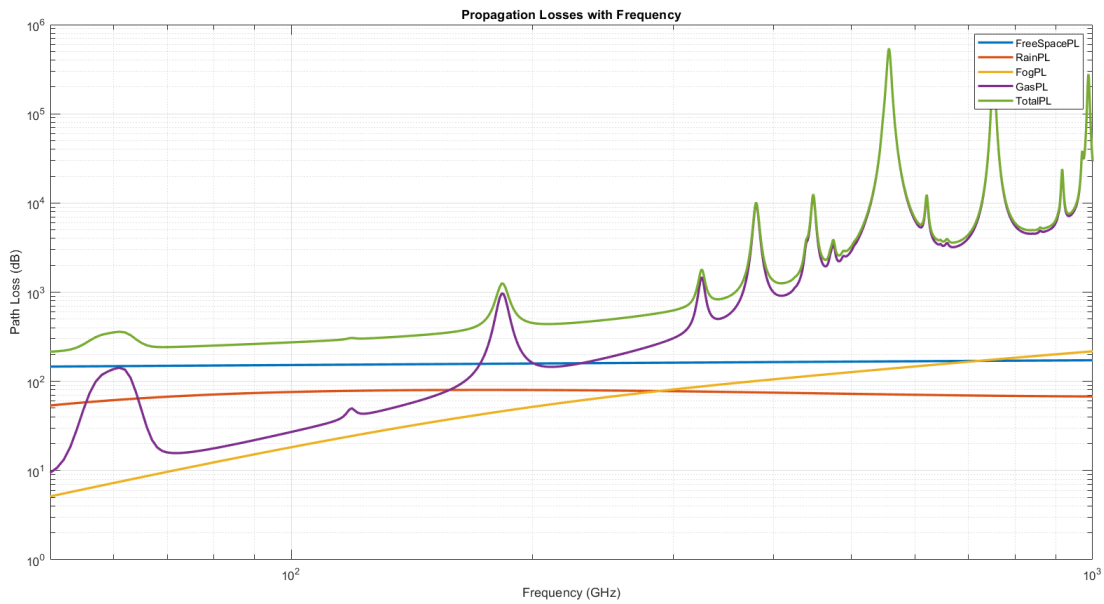


Figure 6: Relationship between Various Path Losses and Frequency - All in One

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 $P_{dB}(0 \text{ km})$,

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

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,

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

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

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

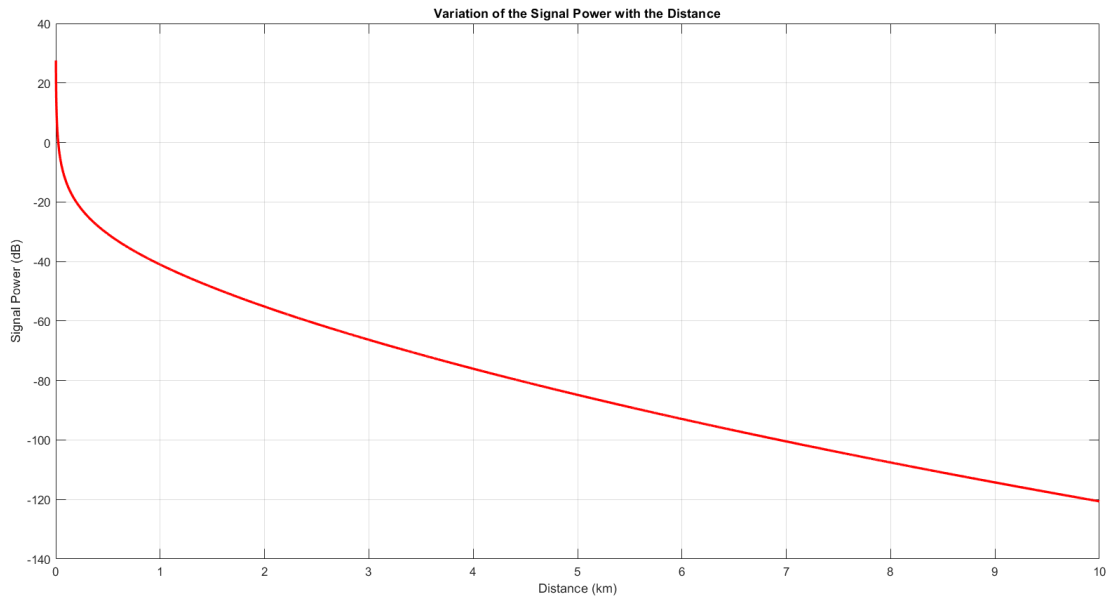


Figure 7: Variation of the Signal Power with the Distance

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

```
1 %% Initialization
2 clear; close all; clc
3 %% ===== Free Space Propagation Loss with Frequency =====
4
5 %Defining the frequency range in GigaHertz
6 f_GHz = 50:1000;
7 %Free Space Path Loss Model obtained through calculations
8 freeSpaceLoss1 = 112.44778322 + 20*log10(f_GHz);
9
10 % Plotting Data
11 plotCurve(freeSpaceLoss1, 'FreeSpacePL')
12
13 %% == Rain, Fog, Atmospheric Gases Attenuations with Frequency ==
14
15 freq = f_GHz*1e9;% Defining the frequency range in Hertz
16 range = 10e3;      % Distance between transmitter and receiver in m
17 rainrate = 20;     % Rain rate in mm/h
18 elev = 0;          % Elevation angle of the propagation path
19 tau = 0;           % Polarization tilt angle of the signal
20 temp = 31;         % Ambient Temperature in celcius
21 dens = 0.5;        % Liquid Water Density in g/m^3
22 rou = 30.4;        % Water Vapor Density in g/m^3
23 p = 101325;        % Atmospheric Pressure in Pa at sea level
24
25 % Calculating Attenuations
26 rainAttenuation = rainpl(range,freq,rainrate,elev,tau);
27 fogAttenuation = fogpl(range,freq,temp,dens);
28 gasAttenuation = gaspl(range,freq,temp, p, rou);
29
30 % Plotting Data
31 plotCurve(rainAttenuation, 'RainPL');
32 plotCurve(fogAttenuation, 'FogPL');
33 plotCurve(gasAttenuation, 'GasPL');
34
35 %% ===== Total Propagation Loss with Frequency =====
36
37 % Calculating Total Attenuation
38 Totalpathloss = freeSpaceLoss1 + rainAttenuation + ...
39                 fogAttenuation +gasAttenuation;
40 % Plotting Data
41 plotCurve(Totalpathloss, 'TotalPL');
42
43 %% ===== Variation of the Signal Power with the Distance =====
44
45 distance = 0:10e3; % Distance between transmitter and receiver in m
46 freq = 50*1e9;     % Choosen frequency value in Hertz
47
48 % Calculating Attenuations with Distance
49 freeSpaceLoss2 = 126.4271833 + 20*log10(distance/(10e3));
50 rainAttenuation = rainpl(distance,freq,rainrate,elev,tau);
51 fogAttenuation = fogpl(distance,freq,temp,dens);
52 gasAttenuation = gaspl(distance,freq,temp, p, rou);
53
54 % Total Path Loss with Distancce
```

```

55 TotalLosswithDistance = freeSpaceLoss2' + rainAttenuation + ...
56                        fogAttenuation +gasAttenuation;
57
58 % Calculating the signal Power with the distance
59 signalPower = 74 - TotalLosswithDistance;
60
61 % Plotting Data
62 plot(distance/10e2, signalPower, 'r','LineWidth', 2);
63 grid on;
64 xlabel('Distance (km)');
65 ylabel('Signal Power (dB)');
66 title('Variation of the Signal Power with the Distance');

```

```

1  function [] = plotCurve(inputArg1,inputArg2)
2  % Function to plot the Curves
3
4  f_GHz = 50:1000;%Defining the frequency range in GigaHertz
5  figure;
6  loglog(f_GHz, inputArg1, 'r', 'LineWidth', 2);
7  grid on;
8  xlabel('Frequency (GHz)');
9
10 if strcmp(inputArg2, 'FreeSpacePL')
11     ylabel('Free Space Path Loss (dB)');
12     title('Free Space Path Loss');
13
14 elseif strcmp(inputArg2, 'RainPL')
15     ylabel('Rain Attenuation (dB)');
16     title('Rain Attenuation for Horizontal Polarization');
17
18 elseif strcmp(inputArg2, 'FogPL')
19     ylabel('Fog Attenuation (dB)');
20     title('Fog Attenuation');
21
22 elseif strcmp(inputArg2, 'GasPL')
23     ylabel('Atmospheric Gases Attenuation (dB)');
24     title('Atmospheric Gases Attenuation');
25
26 elseif strcmp(inputArg2, 'TotalPL')
27     ylabel('Total Path Loss (dB)');
28     title('Total Path Loss');
29 end
30
31 legend(inputArg2);
32 %saveas(gcf,strcat(inputArg2,'.png'));
33 fprintf('Program paused. Press enter to continue.\n');
34 pause;
35 end

```

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.