Department of Electronic and Telecommunication Engineering

University of Moratuwa, Sri Lanka

EN2570 - Digital Signal Processing

Design of an FIR Digital Filter for Prescribed Specifications

(Using the windowing method in conjunction with the Kaiser window)

Project Report

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Contents

**** PDF is clickable***

Note:
Additionally all the materials related to Task can also be found at

1 Modeling the RF propagation Using Matlab

1.1 Relationship between Free Space Path Loss and Frequency

Consider following meanings for the parameters

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

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

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.

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.*

1.3 Variation of the Signal Power with the Distance

Chosen Carrier 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

1.4 Codes

```
%% 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 transceivers 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 transceivers 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
figure;
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');

fprintf('Program paused. Press enter to continue.\n');
pause;

%% ==Sending Voice Signal Over a Noisy Channel - Associated Logic==

freqDeviation = 4000; % Frequency Deviation of the Voice signal
CarrierFreq = 50e9;   % Carrier Frequency

% Frequency range of the Transmitted Signal
freqRange = CarrierFreq - freqDeviation :...
                   CarrierFreq + freqDeviation;

% Calculating Losses
freeSpaceLoss3 = 112.44778322 + 20*log10(freqRange/(1e9));
rainAttenuation = rainpl(range,freqRange,rainrate,elev,tau);
fogAttenuation = fogpl(range,freqRange,temp,dens);
gasAttenuation = gaspl(range,freqRange,temp, p, rou);

% Total Path Loss in the given Frequency Range
TotalPathLoss = freeSpaceLoss3 + rainAttenuation + ...
                              fogAttenuation +gasAttenuation;
% Plotting Data
figure;
```

```
plot(freqRange, TotalPathLoss, 'r', 'LineWidth', 2);
grid on;
xlabel('Frequency (Hz)');
ylabel('Total Path Loss (dB)');
title('Variation of the Path Loss with Frequency');
```

Bibliography

[1] Modeling the Propagation of RF Signals - MATLAB & Simulink - MathWorks India. https://in.mathworks.com/help/phased/examples/modeling-the-propagation-of-rf-signals.html.

[2] P.676 : Attenuation by atmospheric gases. https://www.itu.int/rec/R-REC-P.676-10-201309-S/en.

[3] P.838 : Specific attenuation model for rain for use in prediction methods. https://www.itu.int/rec/R-REC-P.838-3-200503-I/en.

[4] P.840 : Attenuation due to clouds and fog. https://www.itu.int/rec/R-REC-P.840-6-201309-S/en.

[5] Water Vapor and Vapor Pressure. http://hyperphysics.phy-astr.gsu.edu/hbase/Kinetic/watvap.html.