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APPENDIX A: RAIN ATTENUATION DETAILS FOR THE GROUND STATIONS

Table A.1: Rain attenuation at Kampung Sungai Tong

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
10.2045	Circular	0.001	41.7
		0.01	29.8
		0.1	17.0
		1	2.8
10.2045	Vertical	0.001	37.0
		0.01	26.6
		0.1	15.4
		1	2.6
10.2045	Horizontal	0.001	46.7
		0.01	33.1
		0.1	18.8
		1	3.0

Table A.2: Rain attenuation at Batu Kurau

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
5.6611	Circular	0.001	40.3
		0.01	28.5
		0.1	16.0
		1	2.5
5.6611	Vertical	0.001	35.6
		0.01	25.3
		0.1	14.4
		1	2.4
5.6611	Horizontal	0.001	45.4
		0.01	31.8
		0.1	17.7
		1	2.7

Table A.3: Rain attenuation at Taiping

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
5.6595	Circular	0.001	43.4
		0.01	30.7
		0.1	17.4
		1	2.9
5.6595	Vertical	0.001	38.3
		0.01	27.3
		0.1	15.6
		1	2.7
5.6595	Horizontal	0.001	49.0
		0.01	34.4
		0.1	19.3
		1	3.1

Table A.4: Rain attenuation at Kampar

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
7.3555	Circular	0.001	40.1
		0.01	28.4
		0.1	16.1
		1	2.5
7.3555	Vertical	0.001	35.5
		0.01	25.3
		0.1	14.5
		1	2.4
7.3555	Horizontal	0.001	45.1
		0.01	31.8
		0.1	17.8
		1	2.7

Table A.5: Rain attenuation at Bidor

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
7.9996	Circular	0.001	38.9
		0.01	27.5
		0.1	15.5
		1	2.5
7.9996	Vertical	0.001	34.5
		0.01	24.6
		0.1	14.0
		1	2.3
7.9996	Horizontal	0.001	43.7
		0.01	30.7
		0.1	17.2
		1	2.6

Table A.6: Rain attenuation at Tanjung Malim

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
8.3244	Circular	0.001	38.6
		0.01	27.3
		0.1	15.4
		1	2.5
7.8448	Vertical	0.001	34.2
		0.01	24.4
		0.1	13.9
		1	2.3
8.3244	Horizontal	0.001	43.3
		0.01	30.5
		0.1	17.0
		1	2.6

Table A.7: Rain attenuation at Kepong

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
11.8582	Circular	0.001	39.3
		0.01	28.0
		0.1	15.9
		1	2.6
10.7869	Vertical	0.001	34.8
		0.01	24.9
		0.1	14.3
		1	2.4
11.8582	Horizontal	0.001	43.8
		0.01	31.1
		0.1	17.5
		1	2.7

Table A.8: Rain attenuation at Endau

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
7.7126	Circular	0.001	39.4
		0.01	27.9
		0.1	15.7
		1	2.5
8.9737	Vertical	0.001	35.1
		0.01	25.0
		0.1	14.3
		1	2.4
7.7126	Horizontal	0.001	44.3
		0.01	31.1
		0.1	17.4
		1	2.7

Table A.9: Rain attenuation at Jln Kluang Mersing

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
8.0778	Circular	0.001	39.2
		0.01	27.8
		0.1	15.7
		1	2.5
9.5362	Vertical	0.001	35.0
		0.01	25.0
		0.1	14.3
		1	2.4
8.0778	Horizontal	0.001	44.0
		0.01	31.0
		0.1	17.3
		1	2.6

Table A.10: Rain attenuation at Kahang Kluang

Elevation angle (degree)	Polarization (V & H)	Time exceeded percentage (%)	Rain attenuation predicted (dB)
7.4445	Circular	0.001	38.8
		0.01	27.4
		0.1	15.4
		1	2.4
8.6677	Vertical	0.001	34.5
		0.01	24.6
		0.1	14.0
		1	2.3
7.4445	Horizontal	0.001	43.5
		0.01	30.6
		0.1	17.0
		1	2.6

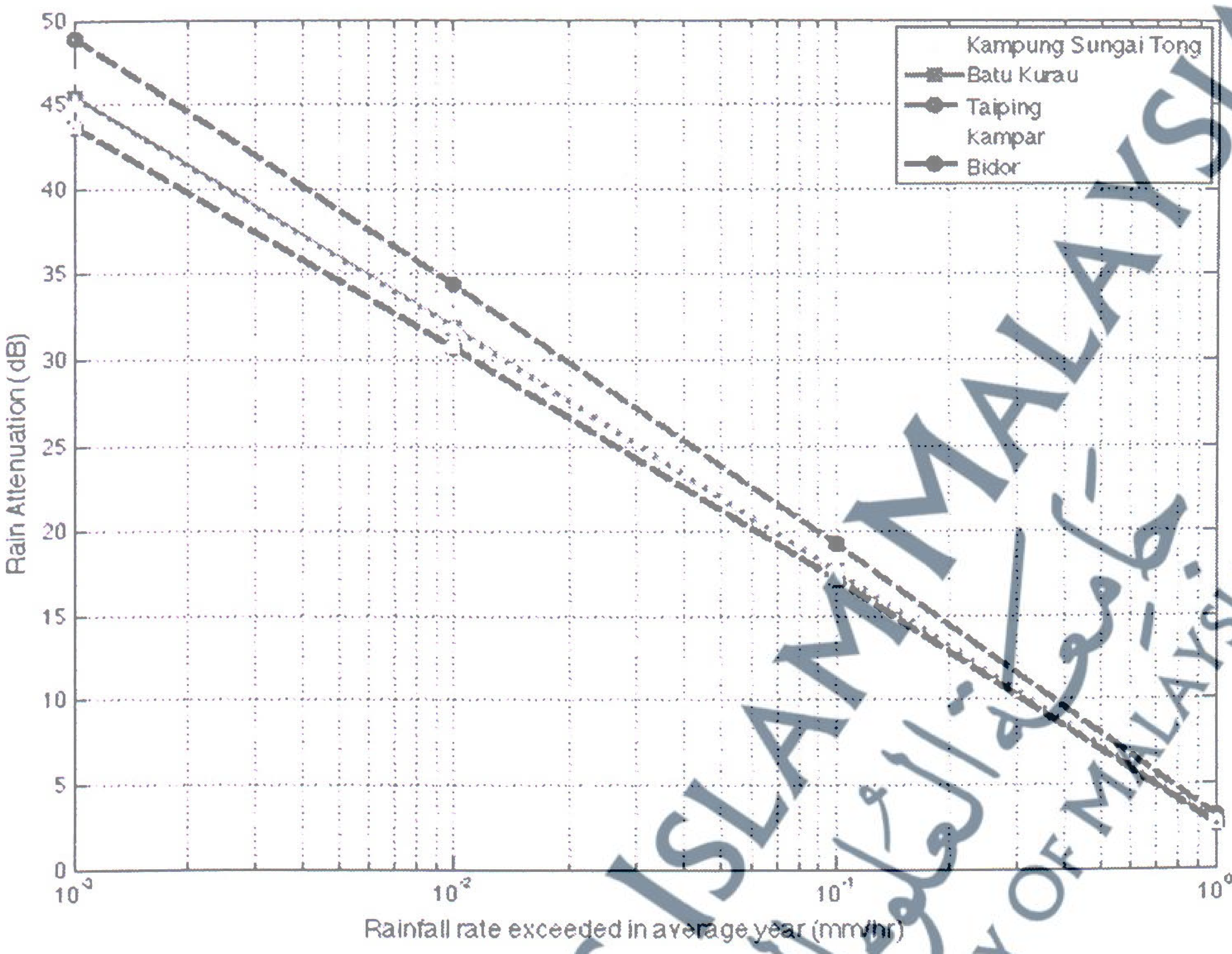

Figure A.1: Relationship between rain attenuation and rainfall average time for the northern part (H polarization)

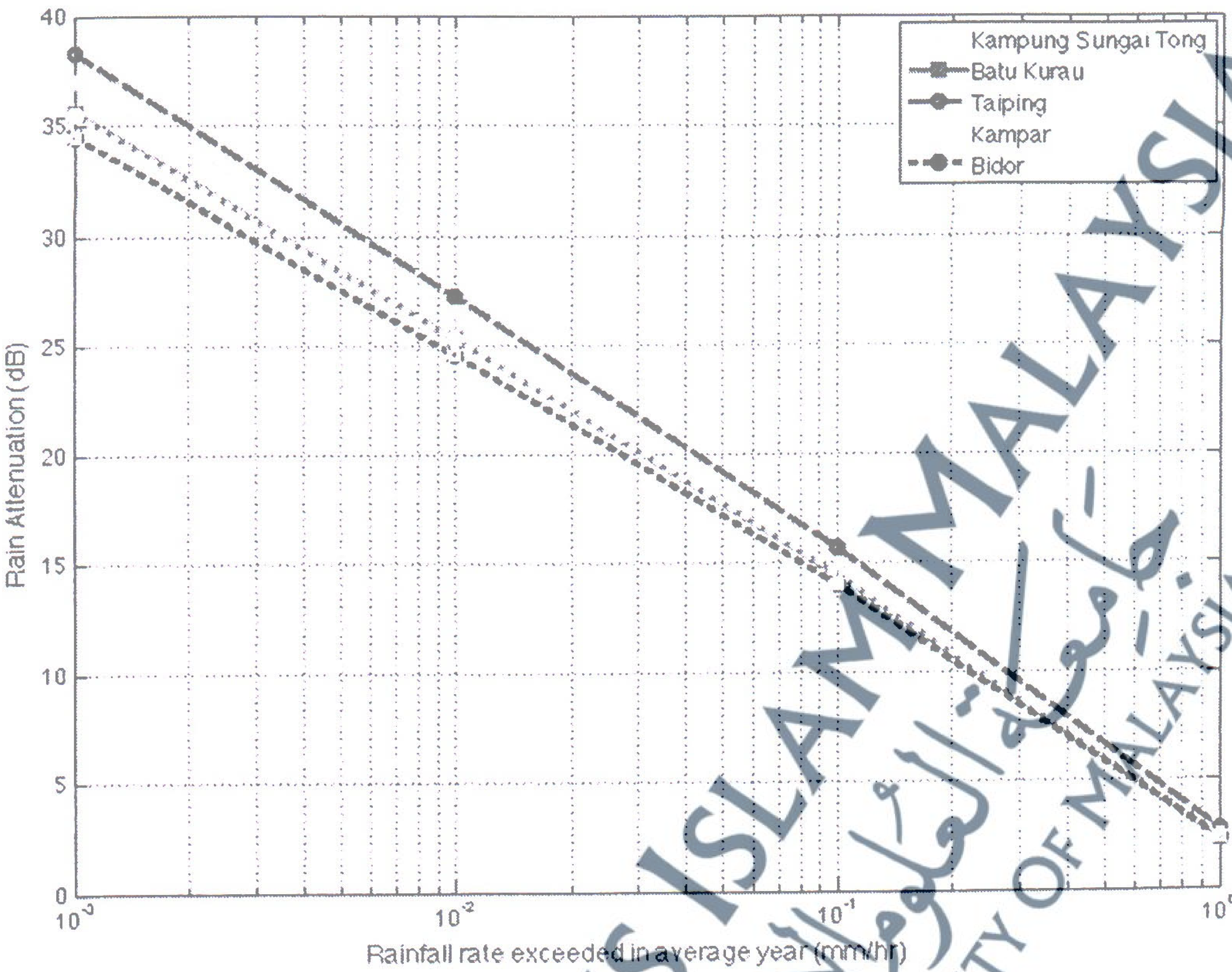

Figure A.3: Relationship between rain attenuation and rainfall average time for the northern part (V polarization)

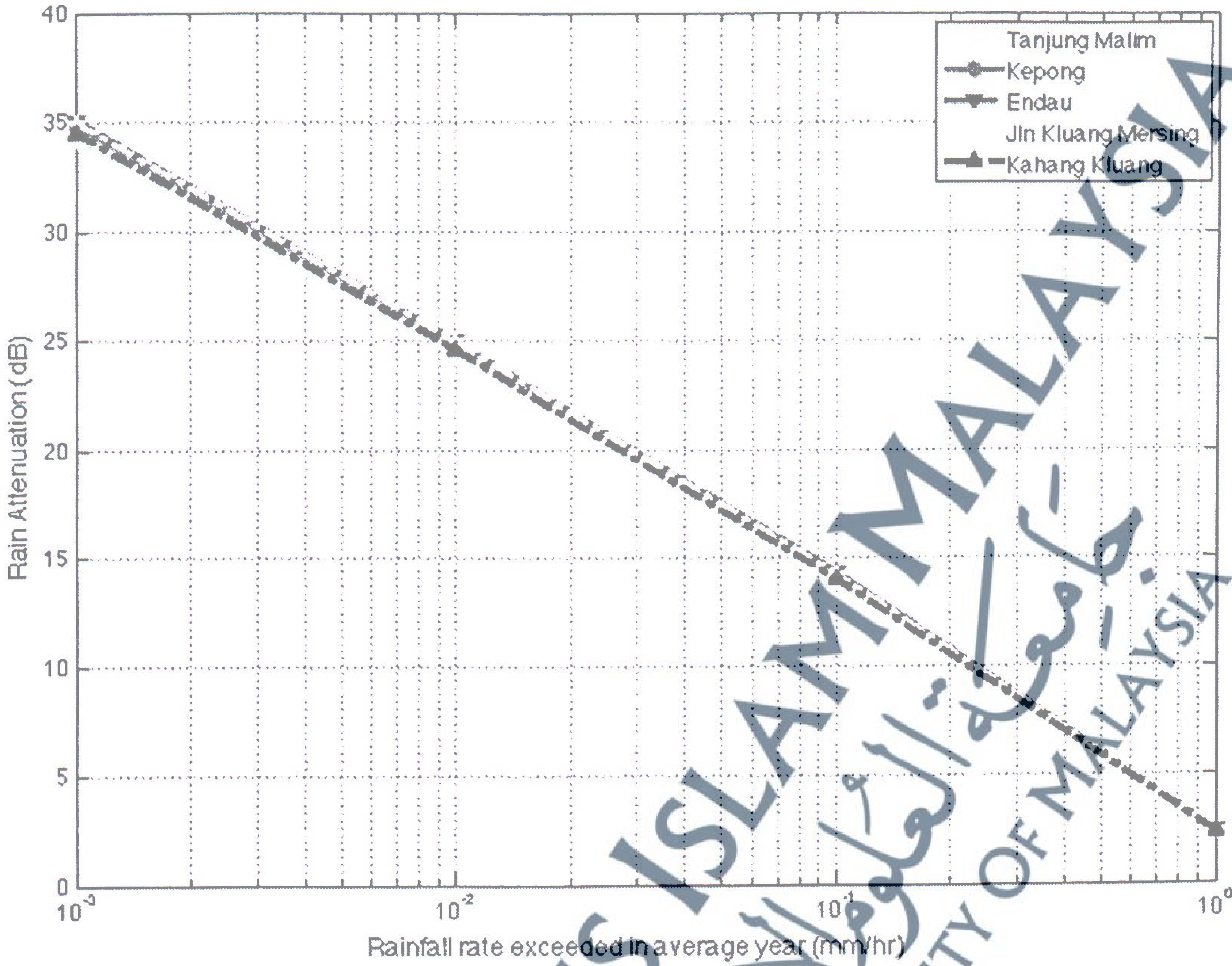

Figure A.4: Relationship between rain attenuation and rainfall average time for the southern part (V polarization)

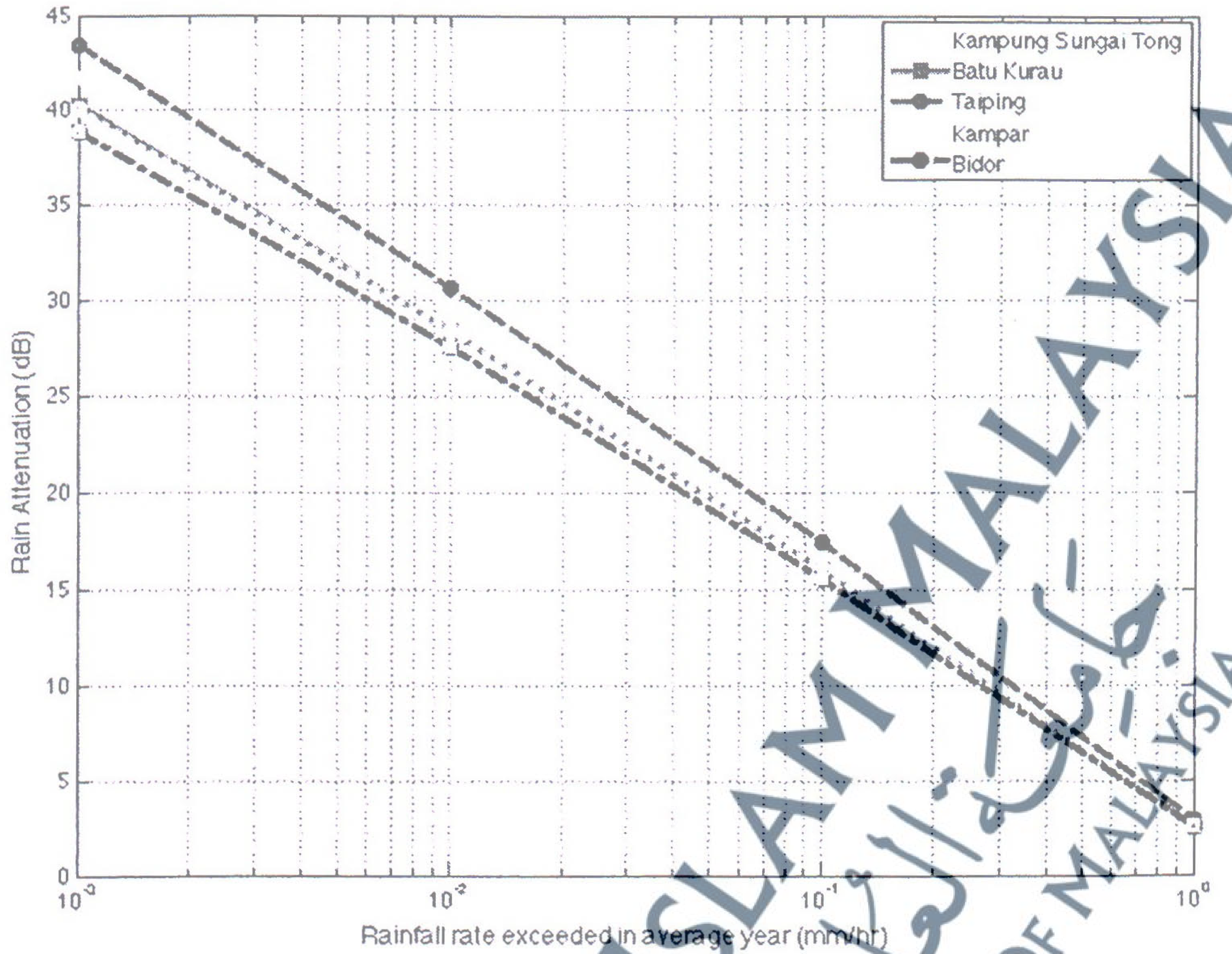

Figure A.5: Relationship between rain attenuation and rainfall average time for the northern part (C polarization)

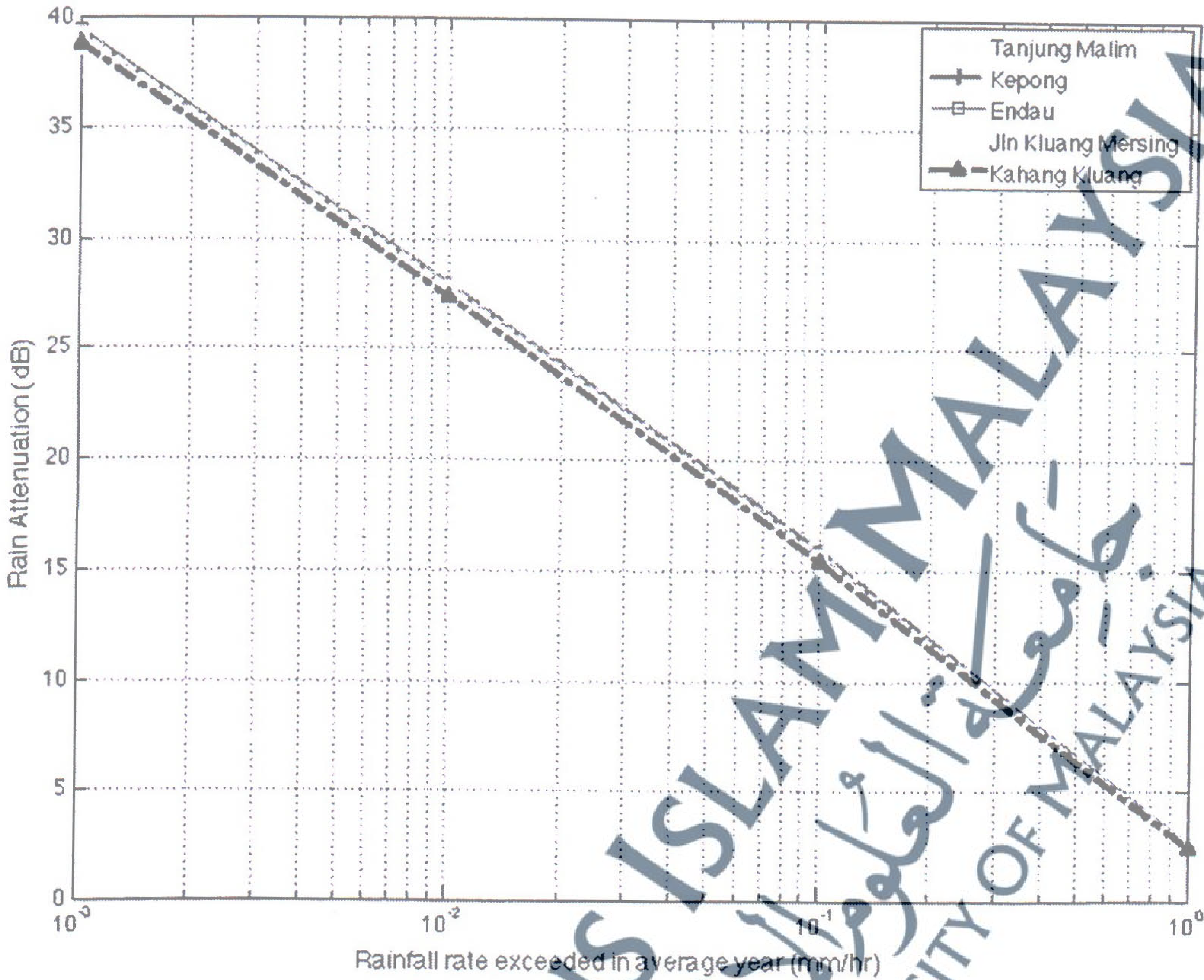

Figure A.6: Relationship between rain attenuation and rainfall average time for the southern part (C polarization)

Table A.11: Coordinates of earth stations

Station Name	Latitude (degree)	Longitude (degree)
Kampung Sungai Tong	5.3556	102.8861
Batu Kurau	4.9792	100.8042
Taiping	4.8625	100.7931
Kampar	4.3056	101.1556
Bidor	4.0486	101.3000
Tanjung Malim	3.6833	101.5236
Kepong	3.2306	101.6375
Endau	2.6500	103.6208
Jln Kluang Mersing	2.2569	103.7361
Kahang Kluang	2.2292	103.5986

APPENDIX B: SUB-MATLAB PROGRAM TO PREDICT THE RAIN ATTENUATION USING MODIFIED ITU-R MODEL AND TO IDENTIFY THE BEST HAPS LOCATION

```
clear all
close all
f=28; %frequency
hR=4.5; %Rain altitude
hs=0.01; %earth station altitude
h=25; rain height
kH=0.2051; %specific attenuation parameter
alphaH=0.9679; %specific attenuation parameter
kV=0.1964; %specific attenuation parameter
alphaV=0.9277;%specific attenuation parameter
taw1=input('Choose the polarization C,V or H : ','s')
if taw1=='C'
    taw=45;
elseif taw1=='V'
        taw=90;
elseif taw1=='H'
            taw=0;

        end
LGN=1.25;
AverageTime=input('Enter The Rain Average Time 1%, 0.1%, 0.01%, 0.001%
: ')
if AverageTime==1
    R001=10.3116;
R0012=9.8189;R0013=11.4713;R0014=9.7088;R0015=9.3246;R0016=9.2224;R0017
=9.2906;R0018=9.4374;R0019=9.3598;R00110=9.2425;
elseif AverageTime==0.1
        R001=74.2402;
R0012=71.7548;R0013=78.4781;R0014=70.9385;R0015=68.0747;R0016=67.3094;R
0017=67.8206;R0018=68.9183;R0019=68.3383;R00110=67.4598;
elseif AverageTime==0.01
R001=138.1689;
R0012=133.8718;R0013=145.4848;R0014=132.4595;R0015=127.5003;R0016=126.1
738;R0017=127.0600;R0018=128.9619;R0019=127.9571;R00110=126.4346;
elseif AverageTime==0.001
        R001=202.0976;
R0012=195.9889;R0013=212.4916;R0014=193.9805;R0015=186.9259;R0016=185.0
383;R0017=186.2993;R0018=189.0054;R0019=187.5758;R00110=185.4095;
end
RA1=[];

% RAIN ATTENUATION PREDICTION FOR THE FIRST STATION

for hap1=5.357286:-0.13861777777777777777777777777778:4.109726 % Y-axis
of HAPS Matrix
for hap2=100.737627:0.23854844444444444444444444444444:102.884563 % x-
axis of HAPS Matrix
phi1=5.357286; % 1st earth station latitude
a1= 5.357286;
```

```
b1=102.884563;
[dDgree] = distance(hap1,hap2,a1,b1); % leg calculation
d1KM=dDgree*111.3222222222222; %adjacent leg calculation (km)
hyp1=sqrt((d1KM^2)+(h^2)); % hypotenuse leg calculation
theta1=acosd(d1KM/hyp1); % elevation angle calculation
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2); %specific
attenuation parameter
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K); %specific
attenuation parameter
%R001=138.1689;
GamaR=K*R001^alpha; %specific attenuation prediction
Ls=(hR-hs)/(sind(theta1)); % slant path length
LG=Ls.*cosd(theta1); %horizontal projection length
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d); % horizontal adjustment factor
zeta=atand((hR-hs)/LG.*r001);
if zeta >theta1
    LR=(LG.*r001)/cosd(theta1); %slant path calculation
else
    LR=(hR-hs)/sind(theta1);
end;
chi=36-phi1;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45)); %vertical reduction
factor
LE=LR*v001; %effective path length
Att=GamaR*LE; %Rain attenuation prediction
x=((hR-hs)/tand(theta1))-LGN; non-affected part of horizontal
projection
Ls2=x/cosd(theta1); % hypotenuse of the non-affected part
LEN=Ls2*v001*GamaR; %rain attenuation of non-affected part
if LG>LGN
    RainAtt1=Att-LEN; %rain attenuation of affected part
else
    RainAtt1=Att;
end
RA1=[RA1,RainAtt1];
disp(RainAtt1)
end
end
RA1=reshape(RA1,10,10); % 10 x 10 matrix


% RAIN ATTENUATION PREDICTION FOR THE SECOND STATION

RA2=[];
for hap12=5.357286:-0.138617777777777777777777777778:4.109726 Y-axis
of HAPS Matrix
for hap22=100.737627:0.238548444444444444444444444444:102.884563 x-
axis of HAPS Matrix
a2= 5.057103;
b2=100.820033;
phi2=5.057103; 2nd earth station latitude
[dDgree2] = distance(hap12,hap22,a2,b2); % adjacent leg calculation
d1KM2=dDgree2*111.3222222222222; %adjacent leg calculation (km)
```

```
hyp2=sqrt((d1KM2^2)+(h^2)); % hypotenuse leg calculation
theta2=acosd(d1KM2/hyp2); % elevation angle calculation
K2=(kH+kV+(kH-kV)*cosd(theta2)*cosd(theta2)*cosd(2*taw))/(2); %specific
attenuation parameter
alpha2=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta2)*cosd(theta2)*cosd(2*taw))/(2*K2); %specific
attenuation parameter
%R0012=133.8718;
GamaR2=K2*R0012^alpha2; %specific attenuation prediction
Ls2=(hR-hs)/(sind(theta2)); % slant path length
LG2=Ls2.*cosd(theta2); %horizontal projection length
c2=0.78.*sqrt(LG2.*GamaR2/f);
d2=0.38.*(1-exp(-2.*LG2));
r0012=1/(1+c2-d2); % horizontal adjustment factor

zeta2=atand((hR-hs)/LG2.*r0012);
if zeta2 >theta2
    LR2=(LG2.*r0012)/cosd(theta2); %slant path calculation
else
    LR2=(hR-hs)/sind(theta2); %slant path calculation
end;
chi2=36-phi2;
e2=31.*(1-exp(-theta2/(1+chi2)));
elf2=sqrt(LR2.*GamaR2)/f.^2;
v0012=1/(1+sqrt(sind(theta2)).*(e2.*elf2-0.45)); %vertical reduction
factor
LE2=LR2*v0012; %effective path length
Att2=GamaR2*LE2; %Rain attenuation prediction
x2=((hR-hs)/tand(theta2))-LGN; %non-affected part of horizontal
projection
Ls2=x2/cosd(theta2); % hypotenuse of the non-affected part
LEN2=Ls2*v0012*GamaR2; %rain attenuation of non-affected part
if LG2>LGN
    RainAtt2=Att2-LEN2; %rain attenuation of affected part
else
    RainAtt2=Att2;
end
RA2=[RA2,RainAtt2];
disp(RainAtt2)
end
end
RA2=reshape(RA2,10,10); % 10 x 10 matrix


% RAIN ATTENUATION PREDICTION FOR THE THIRD STATION

RA3=[];
for hap13=5.357286:-0.138617777777777777777777777778:4.109726 %Y-axis
of HAPS Matrix
for hap23=100.737627:0.238548444444444444444444444444:102.884563% x-
axis of HAPS Matrix
a3= 4.854228;
b3=100.737627;
phi3=4.854228; 3rd earth station latitude
[dDgree3] = distance(hap13,hap23,a3,b3);%adjacent leg calculation
d1KM3=dDgree3*111.3222222222222; %adjacent leg calculation (km)
hyp13=sqrt((d1KM3^2)+(h^2)); % hypotenuse leg calculation
theta13=acosd(d1KM3/hyp13); % elevation angle calculation
```

```
K3=(kH+kV+(kH-kV)*cosd(theta13)*cosd(theta13)*cosd(2*taw))/(2);
%specific attenuation parameter
alpha3=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta13)*cosd(theta13)*cosd(2*taw))/(2*K3); %specific
attenuation parameter
%R0013=145.4848;
GamaR3=K3*R0013^alpha3; %specific attenuation prediction
Ls3=(hR-hs)/(sind(theta13)); % slant path length
LG3=Ls3.*cosd(theta13); %horizontal projection length
c3=0.78.*sqrt(LG3.*GamaR3/f);
d3=0.38.*(1-exp(-2.*LG3));
r0013=1/(1+c3-d3); % horizontal adjustment factor
zeta3=atand((hR-hs)/LG3.*r0013);
if zeta3 >theta13
    LR3=(LG3.*r0013)/cosd(theta13); %slant path calculation
else
    LR3=(hR-hs)/sind(theta13); %slant path calculation
end;
chi3=36-phi3;
e3=31.*(1-exp(-theta13/(1+chi3)));
elf3=sqrt(LR3.*GamaR3)/f.^2;
v0013=1/(1+sqrt(sind(theta13)).*(e3.*elf3-0.45)); %vertical reduction
factor
LE3=LR3*v0013; %effective path length
Att3=GamaR3*LE3; %Rain attenuation prediction
x3=((hR-hs)/tand(theta13))-LGN; %non-affected part of horizontal
projection
Ls23=x3/cosd(theta13); % hypotenuse of the non-affected part
LEN3=Ls23*v0013*GamaR3; %rain attenuation of non-affected part
if LG3>LGN
    RainAtt3=Att3-LEN3; %rain attenuation of affected part
else
    RainAtt3=Att3;
end
RA3=[RA3,RainAtt3];
disp(RainAtt3)
end
end
RA3=reshape(RA3,10,10); % 10 x 10 matrix


% RAIN ATTENUATION PREDICTION FOR THE FOURTH STATION

RA4=[];
for hap14=5.357286:-0.138617777777777777777777777778:4.109726 %Y-axis
of HAPS Matrix
for hap24=100.737627:0.238548444444444444444444444444:102.884563% x-
axis of HAPS Matrix
a4= 4.311012;
b4=101.151872;
phi4=4.311012; %earth station latitude
[dDgree4] = distance(hap14,hap24,a4,b4); % adjacent leg calculation
d1KM4=dDgree4*111.3222222222222;  % adjacent leg calculation (km)
hyp14=sqrt((d1KM4^2)+(h^2)); % hypotenuse leg calculation
theta14=acosd(d1KM4/hyp14); % elevation angle calculation
K4=(kH+kV+(kH-kV)*cosd(theta14)*cosd(theta14)*cosd(2*taw))/(2);
%specific attenuation parameter
alpha4=(kH*alphaH+kV*alphaV+(kH*alphaH-
```

```
kV*alphaV)*cosd(theta14)*cosd(theta14)*cosd(2*taw))/(2*K4); %specific
attenuation parameter
%R0014=132.4595;
GamaR4=K4*R0014^alpha4; %specific attenuation prediction
Ls4=(hR-hs)/(sind(theta14)); % slant path length
LG4=Ls4.*cosd(theta14); %horizontal projection length
c4=0.78.*sqrt(LG4.*GamaR4/f);
d4=0.38.*(1-exp(-2.*LG4));
r0014=1/(1+c4-d4); % horizontal adjustment factor
zeta4=atand((hR-hs)/LG4.*r0014);
if zeta4 >theta14
    LR4=(LG4.*r0014)/cosd(theta14); %slant path calculation
else
    LR4=(hR-hs)/sind(theta14); %slant path calculation
end;
chi4=36-phi4;
e4=31.*(1-exp(-theta14/(1+chi4)));
elf4=sqrt(LR4.*GamaR4)/f.^2;
v0014=1/(1+sqrt(sind(theta14)).*(e4.*elf4-0.45)); %vertical reduction
factor
LE4=LR4*v0014; %effective path length
Att4=GamaR4*LE4; %Rain attenuation prediction
x4=((hR-hs)/tand(theta14))-LGN; %non-affected part of horizontal
projection
Ls24=x4/cosd(theta14); % hypotenuse of the non-affected part
LEN4=Ls24*v0014*GamaR4; %rain attenuation of non-affected part
if LG4>LGN
    RainAtt4=Att4-LEN4; %rain attenuation of the affected part
else
    RainAtt4=Att4;
end
RA4=[RA4,RainAtt4];
disp(RainAtt4)
end
end
RA4=reshape(RA4,10,10); % 10 x 10 matrix


% RAIN ATTENUATION PREDICTION FOR THE FIFTH STATION

RA5=[];
for hap15=5.357286:-0.138617777777777777777777777778:4.109726
for hap25=100.737627:0.238548444444444444444444444444:102.884563
a5=4.109726;
b5=101.282444;
phi5=4.109726;
[dDgree5] = distance(hap15,hap25,a5,b5);%
d1KM5=dDgree5*111.3222222222222;
hyp15=sqrt((d1KM5^2)+(h^2));
theta15=acosd(d1KM5/hyp15);
K5=(kH+kV+(kH-kV)*cosd(theta15)*cosd(theta15)*cosd(2*taw))/(2);
alpha5=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta15)*cosd(theta15)*cosd(2*taw))/(2*K5);
%R0015=127.5003;
GamaR5=K5*R0015^alpha5;
Ls5=(hR-hs)/(sind(theta15));
LG5=Ls5.*cosd(theta15);
c5=0.78.*sqrt(LG5.*GamaR5/f);
```

```
d5=0.38.*(1-exp(-2.*LG5));
r0015=1/(1+c5-d5);
zeta5=atand((hR-hs)/LG5.*r0015);
if zeta5 >theta15
    LR5=(LG5.*r0015)/cosd(theta15);
else
    LR5=(hR-hs)/sind(theta15);
end;
chi5=36-phi5;
e5=31.*(1-exp(-theta15/(1+chi5)));
elf5=sqrt(LR5.*GamaR5)/f.^2;
v0015=1/(1+sqrt(sind(theta15)).*(e5.*elf5-0.45));
LE5=LR5*v0015;
Att5=GamaR5*LE5;
x5=((hR-hs)/tand(theta15))-LGN;
Ls25=x5/cosd(theta15);
LEN5=Ls25*v0015*GamaR5;
if LG5>LGN
    RainAtt5=Att5-LEN5;
else
    RainAtt5=Att5;
end
RA5=[RA5,RainAtt5];
disp(RainAtt5)

end
end
RA5=reshape(RA5,10,10); % 10 x 10 matrix



% RAIN ATTENUATION PREDICTION FOR THE SIXTH STATION

RA6=[];
for hap16=3.682043:-0.1615821111111111111111111111:2.227804
for hap26=101.523710:0.245709:103.735091
phi6=3.682043;
a16= 3.682043;
b16=101.523710;
[dDgree6] = distance(hap16,hap26,a16,b16);
d1KM6=dDgree6*111.3222222222222;
hyp16=sqrt((d1KM6^2)+(h^2));
theta16=acosd(d1KM6/hyp16);
K6=(kH+kV+(kH-kV)*cosd(theta16)*cosd(theta16)*cosd(2*taw))/(2);
alpha6=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta16)*cosd(theta16)*cosd(2*taw))/(2*K6);
%R0016=126.1738;
GamaR6=K6*R0016^alpha6;
Ls6=(hR-hs)/(sind(theta16));
LG6=Ls6.*cosd(theta16);
c6=0.78.*sqrt(LG6.*GamaR6/f);
d6=0.38.*(1-exp(-2.*LG6));
r0016=1/(1+c6-d6);
zeta6=atand((hR-hs)/LG6.*r0016);
if zeta6 >theta16
    LR6=(LG6.*r0016)/cosd(theta16);
else
    LR6=(hR-hs)/sind(theta16);
```

```
end;
chi6=36-phi6;
e6=31.*(1-exp(-theta16/(1+chi6)));
elf6=sqrt(LR6.*GamaR6)/f.^2;
v0016=1/(1+sqrt(sind(theta16)).*(e6.*elf6-0.45));
LE6=LR6*v0016;
Att6=GamaR6*LE6;
x6=((hR-hs)/tand(theta16))-LGN;
Ls26=x6/cosd(theta16);
LEN6=Ls26*v0016*GamaR6;
if LG6>LGN
    RainAtt6=Att6-LEN6;
else
    RainAtt6=Att6;
end
RA6=[RA6,RainAtt6];
disp(RainAtt6)
end
end
RA6=reshape(RA6,10,10); % 10 x 10 matrix



% RAIN ATTENUATION PREDICTION FOR THE SEVENTH STATION

RA7=[];
for hap17=3.682043:-0.1615821111111111111111111111111:2.227804
for hap27=101.523710:0.245709:103.735091
phi7=3.228569;
a27=3.228569;
b27=101.637347;
[dDgree7] = distance(hap17,hap27,a27,b27);
d1KM7=dDgree7*111.3222222222222;
hyp17=sqrt((d1KM7^2)+(h^2));
theta17=acosd(d1KM7/hyp17);
K7=(kH+kV+(kH-kV)*cosd(theta17)*cosd(theta17)*cosd(2*taw))/(2);
alpha7=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta17)*cosd(theta17)*cosd(2*taw))/(2*K7);
%R0017=127.0600;
GamaR7=K7*R0017^alpha7;
Ls7=(hR-hs)/(sind(theta17));
LG7=Ls7.*cosd(theta17);
c7=0.78.*sqrt(LG7.*GamaR7/f);
d7=0.38.*(1-exp(-2.*LG7));
r0017=1/(1+c7-d7);
zeta7=atand((hR-hs)/LG7.*r0017);
if zeta7 >theta17
    LR7=(LG7.*r0017)/cosd(theta17);
else
    LR7=(hR-hs)/sind(theta17);
end;
chi7=36-phi7;
e7=31.*(1-exp(-theta17/(1+chi7)));
elf7=sqrt(LR7.*GamaR7)/f.^2;
v0017=1/(1+sqrt(sind(theta17)).*(e7.*elf7-0.45));
LE7=LR7*v0017;
Att7=GamaR7*LE7;
x7=((hR-hs)/tand(theta17))-LGN;
```

```
Ls27=x7/cosd(theta17);
LEN7=Ls27*v0017*GamaR7;
if LG7>LGN
    RainAtt7=Att7-LEN7;
else
    RainAtt7=Att7;
end
RA7=[RA7,RainAtt7];
disp(RainAtt7)
end
end
RA7=reshape(RA7,10,10); % 10 x 10 matrix


% RAIN ATTENUATION PREDICTION FOR THE EIGHTH STATION

RA8=[];
for hap18=3.682043:-0.161582111111111111111111111111:2.227804
for hap28=101.523710:0.245709:103.735091
phi8=2.648119;
a38= 2.648119;
b38=103.620668;
[dDgree8] = distance(hap18,hap28,a38,b38);
d1KM8=dDgree8*111.3222222222222;
hyp18=sqrt((d1KM8^2)+(h^2));
theta18=acosd(d1KM8/hyp18);
K8=(kH+kV+(kH-kV)*cosd(theta18)*cosd(theta18)*cosd(2*taw))/(2);
alpha8=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta18)*cosd(theta18)*cosd(2*taw))/(2*K8);
%R0018=128.9619;
GamaR8=K8*R0018^alpha8;
Ls8=(hR-hs)/(sind(theta18));
LG8=Ls8.*cosd(theta18);
c8=0.78.*sqrt(LG8.*GamaR8/f);
d8=0.38.*(1-exp(-2.*LG8));
r0018=1/(1+c8-d8);
zeta8=atand((hR-hs)/LG8.*r0018);
if zeta8 >theta18
    LR8=(LG8.*r0018)/cosd(theta18);
else
    LR8=(hR-hs)/sind(theta18);
end;
chi8=36-phi8;
e8=31.*(1-exp(-theta18/(1+chi8)));
elf8=sqrt(LR8.*GamaR8)/f.^2;
v0018=1/(1+sqrt(sind(theta18)).*(e8.*elf8-0.45));
LE8=LR8*v0018;
Att8=GamaR8*LE8;
x8=((hR-hs)/tand(theta18))-LGN;
Ls28=x8/cosd(theta18);
LEN8=Ls28*v0018*GamaR8;
if LG8>LGN
    RainAtt8=Att8-LEN8;
else
    RainAtt8=Att8;
end
RA8=[RA8,RainAtt8];
disp(RainAtt8)
```

```
end
end
RA8=reshape(RA8,10,10); % 10 x 10 matrix

% RAIN ATTENUATION PREDICTION FOR THE NINTH STATION

RA9=[];
for hap19=3.682043:-0.16158211111111111111111111111111:2.227804
for hap29=101.523710:0.245709:103.735091
phi9=2.229204;
a49=2.229204;
b49=103.598663;
[dDgree9] = distance(hap19,hap29,a49,b49);
d1KM9=dDgree9*111.3222222222222;
hyp19=sqrt((d1KM9^2)+(h^2));
theta19=acosd(d1KM9/hyp19);
K9=(kH+kV+(kH-kV)*cosd(theta19)*cosd(theta19)*cosd(2*taw))/(2);
alpha9=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta19)*cosd(theta19)*cosd(2*taw))/(2*K9);
%R0019=127.9571;
GamaR9=K9*R0019^alpha9;
Ls9=(hR-hs)/(sind(theta19));
LG9=Ls9.*cosd(theta19);
c9=0.78.*sqrt(LG9.*GamaR9/f);
d9=0.38.*(1-exp(-2.*LG9));
r0019=1/(1+c9-d9);
zeta9=atand((hR-hs)/LG9.*r0019);
if zeta9 >theta19
    LR9=(LG9.*r0019)/cosd(theta19);
else
    LR9=(hR-hs)/sind(theta19);
end;
chi9=36-phi9;
e9=31.*(1-exp(-theta19/(1+chi9)));
elf9=sqrt(LR9.*GamaR9)/f.^2;
v0019=1/(1+sqrt(sind(theta19)).*(e9.*elf9-0.45));
LE9=LR9*v0019;
Att9=GamaR9*LE9;
x9=((hR-hs)/tand(theta19))-LGN;
Ls29=x9/cosd(theta19);
LEN9=Ls29*v0019*GamaR9;
if LG9>LGN
    RainAtt9=Att9-LEN9;
else
    RainAtt9=Att9;
end
disp(RainAtt9)
RA9=[RA9,RainAtt9];
end
end
RA9=reshape(RA9,10,10); % 10 x 10 matrix


% RAIN ATTENUATION PREDICTION FOR THE TENTH STATION

RA10=[];
for hap110=3.682043:-0.16158211111111111111111111111111:2.227804
for hap210=101.523710:0.245709:103.735091
```

```
phi10= 2.227804;
a510= 2.227804;
b510=103.735091;
[dDgree10] = distance(hap110,hap210,a510,b510);
d1KM10=dDgree10*111.3222222222222;
hyp110=sqrt((d1KM10^2)+(h^2));
theta110=acosd(d1KM10/hyp110);
K10=(kH+kV+(kH-kV)*cosd(theta110)*cosd(theta110)*cosd(2*taw))/(2);
alpha10=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta110)*cosd(theta110)*cosd(2*taw))/(2*K10);
%R00110=126.4346;
GamaR10=K10*R00110^alpha10;
Ls10=(hR-hs)/(sind(theta110));
LG10=Ls10.*cosd(theta110);
c10=0.78.*sqrt(LG10.*GamaR10/f);
d10=0.38.*(1-exp(-2.*LG10));
r00110=1/(1+c10-d10);
zeta10=atand((hR-hs)/LG10.*r00110);
if zeta10 >theta110
    LR10=(LG10.*r00110)/cosd(theta110);
else
    LR10=(hR-hs)/sind(theta110);
end;
chi10=36-phi10;
e10=31.*(1-exp(-theta110/(1+chi10)));
elf10=sqrt(LR10.*GamaR10)/f.^2;
v00110=1/(1+sqrt(sind(theta110)).*(e10.*elf10-0.45));
LE10=LR10*v00110;
Att10=GamaR10*LE10;
x10=((hR-hs)/tand(theta110))-LGN;
Ls210=x10/cosd(theta110);
LEN10=Ls210*v00110*GamaR10;
if LG10>LGN
    RainAtt10=Att10-LEN10;
else
    RainAtt10=Att10;
end
disp(RainAtt10)
RA10=[RA10,RainAtt10];
end
end
RA10=reshape(RA10,10,10); % 10 x 10 matrix
maxRA1=zeros(size(RA1));%% Matrix containing the 100 Maximum values
only obtained from the first 5 matrixes.
maxRA2=zeros(size(RA1));%% Matrix containing the 100 Maximum values
only obtained from the second 5 matrixes.
for ctr=1:size(RA1,1)
    for ctc=1:size(RA1,2)
        v1=[RA1(ctr,ctc), RA2(ctr,ctc),RA3(ctr,ctc),
RA4(ctr,ctc),RA5(ctr,ctc)]
        v2=[RA6(ctr,ctc),RA7(ctr,ctc), RA8(ctr,ctc),RA9(ctr,ctc),
RA10(ctr,ctc)];
        maxv1=max(v1);% compare each element in each Matrix with the
elements located in the same position only in the other Matrixes to
find the maximum value
        maxv2=max(v2);
        maxRA1(ctr,ctc)=maxv1;
        maxRA2(ctr,ctc)=maxv2;
```

```
    end
end
m1=min(maxRA1(:));%Find the Minimum Value
[rmin1,cmin1]=find(maxRA1==m1);%Find it's location in the Matrix
m2=min(maxRA2(:));%Find the Minimum Value
[rmin2,cmin2]=find(maxRA2==m2);%Find it's location in the Matrix
disp('Minimum Value first 5 matrix')
disp(m1);
disp('location row - column');
disp([rmin1,cmin1])
disp('Minimum Value second 5 matrix')
disp(m2);
disp('location row - column');
disp([rmin2,cmin2])
```

APPENDIX C: SUB-MATLAB PROGRAM TO PREDICT THE RAIN ATTENUATION BASED ON ITU-R MODEL

```
f=28; %frequency
hR=4.5;%rain height
hs=0.025; % earth station height
h=25; %HAPS altitude
kH=0.2051; %specific attenuation parameter
alphaH=0.9679; %specific attenuation parameter
kV=0.1964; %specific attenuation parameter
alphaV=0.9277; %specific attenuation parameter
taw=45; %polarization tilt angle
phi=3.8083; %ground station latitude
theta1=70; %elevation angle
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2); %specific
attenuation parameter
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K); %specific
attenuation parameter
R001=121.3373; %rainfall rate
GamaR=K*R001^alpha; %specific attenuation prediction
Ls=(hR-hs)/(sind(theta1)); %slant path length
LG=Ls.*cosd(theta1); horizontal projection length
% horizontal reduction factor ro.o1
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
%the vertical adjustment factor vo.o1
zeta=atand((hR-hs)/LG.*r001);
if zeta >thetal
    LR=(LG.*r001)/cosd(theta1); %slant path
else
    LR=(hR-hs)/sind(theta1);
end;
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45)); %vertical reduction
factor
LE=LR*v001; %effective path length
Att=GamaR*LE; %rain attenuation prediction
```

APPENDIX D: SUB-MATLAB PROGRAM TO CALCULATE DROP SIZE DISTRIBUTION

```
radius=0.001:0.001:0.01; %raindrop radius
No=8*10^3;      %Palmar-Marshal constant
R1=10;          %rainfall rate
AS1=8.2*R1^-0.21; %DSD for 10mm rainfall
N1D=No*exp(-AS1*radius);
R2=50;          %rainfall rate
AS2=8.2*R2^-0.21;
N2D=No*exp(-AS2*radius); %DSD for 50mm rainfall
R3=130;         %rainfall rate
AS3=8.2*R3^-0.21;
N3D=No*exp(-AS3*radius); %DSD for 130mm rainfall
grid on;
hold on;
plot(radius,N1D,'b');
plot(radius,N2D,'g');
plot(radius,N3D,'r');
xlabel('Raindrop Diameter (mm)');
ylabel('Drop Size Distribution');
legend('R=10mm','R=50mm','R=130mm')
```

APPENDIX E: SUB-MATLAB PROGRAM TO CALCULATE THE SITE DIVERSITY

```
% Taiping Site Diversity
for d=0.5:0.5:5; % separation distance between main and joint sites
A=30.7167; % Rain attenuation at the main site
theta=5.6595; %elevation angle
f=28; %frequency
phi=90; %propagation path azimuth angle
a=(0.78*A)-(1.94*(1-(exp(-0.11*A))));
b=0.59*(1-(exp(-0.1*A)));
Gd=a*(1-(exp(-b*d))); %gain parameter
Gf=exp(-0.025*f); %frequency parameter
Gtheta=1+(0.006*theta); %elevation angle dependent
Gphi=1+(0.002*phi); %baseline dependent
GsD=Gd*Gf*Gtheta*Gphi; %diversity gain
disp(GsD)
end
% Kepong Site Diversity
for d=0.5:0.5:5; % separation distance between main and joint sites
A=27.9667; % Rain attenuation at the main site
theta=11.8582; %elevation angle
f=28; %frequency
phi=90; %propagation path azimuth angle
a=(0.78*A)-(1.94*(1-(exp(-0.11*A))));
b=0.59*(1-(exp(-0.1*A)));
Gd=a*(1-(exp(-b*d))); %gain parameter
Gf=exp(-0.025*f); %frequency parameter
Gtheta=1+(0.006*theta); %elevation angle dependent
Gphi=1+(0.002*phi); %baseline dependent
GsD=Gd*Gf*Gtheta*Gphi;
disp(GsD) %diversity gain
end
```

APPENDIX F: SUB-MATLAB PROGRAM TO PREDICT THE RAIN ATTENUATION FOR THE NON-STATIONARY SOURCES (NORTH PART)

```
% FIRST STATION

f=28; %frequency
hR=4.5; %rain height
hs=0.025; %station height
h=25; %HAPS height
kH=0.2051; %specific attenuation parameter
alphaH=0.9679; %specific attenuation parameter
kV=0.1964; %specific attenuation parameter
alphaV=0.9277; %specific attenuation parameter
taw=45; %polarization tilt angle
theta1=10.2045; %elevation angle
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2); %specific
attenuation parameter
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K); %specific
attenuation parameter
R001=138.1689; %rainfall rate
GamaR=K*R001^alpha; %specific attenuation
phi=5.357286; %ground station latitude
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
%Cloud speed assumed to be 5km/hr
Vcloud=(50/3600);%(5/3600):0.25:2.8; %velocity km/s
disCloud=Vcloud*t;
dis2=dis-disCloud; %Cloud velocity direction
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
c=0.78.*sqrt(LG.*GamaR/f); % horizontal reduction factor ro.ol
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45)); %the vertical adjustment
factor vo.ol
LE=LR*v001; %effective path length
Att=GamaR*LE; %total rain attenuation
Lod9=LGN/cosd(theta1); %slant path length affected by rain at 0.001s
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1)); %signal path length under the rain height
hypNon=hyp-Lodd; %non-affected path lenght
```

```
LEN=hypNon*v001*GamaR; non-affected path rain attenuation
if LG>LGN
    RainAtt=Att-LEN;
else
    RainAtt=Att;
end
oo=Ls-hypNon; %signal part length affected by rain

   disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN % total signal part length rain affected by
rain
    Lod=xn/(cosd(theta1)); % total path length of the affected signal
part at 0.001 s
    if Lod>Ls;
        Lod=Ls;
    else
        Lod=Lod;
    end
   % LsNN=Ls-Lod;
   %RAtt=LsNN*GamaR;
   Lod22=RCS/cosd(theta1); %path length under the rain cell
   if Lod22>Ls
       Lod22=Ls;
   else
       Lod22=Lod22;
   end
   Ls3=(Lod22)-Lod;

   RAtt=Ls3*v001*GamaR;

   disp(RAtt)
end


% SECOND STATION

f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
theta1=5.6611;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=133.8718;
GamaR=K*R001^alpha;
phi=5.057103;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
```

```
RCS=1.25;%Rain cell size

%Cloud speed assumed to be 5km/hr
Vcloud=(50/3600);%(5/3600):0.25:2.8; %velocity km/s
disCloud=Vcloud*t;
%Cloud velocity direction
dis2=dis-disCloud;
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
% horizontal reduction factor ro.o1
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
%the vertical adjustment factor vo.o1
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45));
LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
    RainAtt=Att-LEN;
else
    RainAtt=Att;
end
oo=Ls-hypNon;

   disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
    Lod=xn/(cosd(theta1));
    if Lod>Ls;
        Lod=Ls;
    else
        Lod=Lod;
    end
   % LsNN=Ls-Lod;
   %RAtt=LsNN*GamaR;
   Lod22=RCS/cosd(theta1);
   if Lod22>Ls
       Lod22=Ls;
   else
       Lod22=Lod22;
   end
   Ls3=(Lod22)-Lod;
RAtt=Ls3*v001*GamaR;
```

```
disp(RAtt)
end

% THIRD STATION

f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
theta1=5.6595;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=145.4848;
GamaR=K*R001^alpha;
phi=4.854228;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
%Cloud speed assumed to be 5km/hr
Vcloud=(50/3600);%(5/3600):0.25:2.8; %velocity km/s
disCloud=Vcloud*t;
%Cloud velocity direction
dis2=dis-disCloud;
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
% horizontal reduction factor ro.01
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
%the vertical adjustment factor vo.01
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45));
LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
    RainAtt=Att-LEN;
```

```
else
    RainAtt=Att;
end
oo=Ls-hypNon;
disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
    Lod=xn/(cosd(theta1));
    if Lod>Ls;
        Lod=Ls;
    else
        Lod=Lod;
    end
   % LsNN=Ls-Lod;
   %RAtt=LsNN*GamaR;
   Lod22=RCS/cosd(theta1);
   if Lod22>Ls
       Lod22=Ls;
   else
       Lod22=Lod22;
   end
   Ls3=(Lod22)-Lod;
RAtt=Ls3*v001*GamaR;
   disp(RAtt)
end

% FOURTH STATION
f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
theta1=7.3555;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=132.4595;
GamaR=K*R001^alpha;
phi=4.311012;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
%Cloud speed assumed to be 5km/hr
Vcloud=(50/3600);%(5/3600):0.25:2.8; %velocity km/s
disCloud=Vcloud*t;
%Cloud velocity direction
dis2=dis-disCloud;
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
% horizontal reduction factor ro.ol
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
```

```
r001=1/(1+c-d);
%the vertical adjustment factor vo.o1
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45));
LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
    RainAtt=Att-LEN;
else
    RainAtt=Att;
end
oo=Ls-hypNon;
disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
    Lod=xn/(cosd(theta1));
    if Lod>Ls;
        Lod=Ls;
    else
        Lod=Lod;
    end
   % LsNN=Ls-Lod;
   %RAtt=LsNN*GamaR;
   Lod22=RCS/cosd(theta1);
   if Lod22>Ls
       Lod22=Ls;
   else
       Lod22=Lod22;
   end
   Ls3=(Lod22)-Lod;
RAtt=Ls3*v001*GamaR;
disp(RAtt)
end


% FIFTH STATION
f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
```

```
theta1=7.9996;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=127.5003;
GamaR=K*R001^alpha;
phi=4.109726;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
%Cloud speed assumed to be 5km/hr
Vcloud=(50/3600);%(5/3600):0.25:2.8; %velocity km/s
disCloud=Vcloud*t;
%Cloud velocity direction
dis2=dis-disCloud;
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
% horizontal reduction factor ro.o1
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
%the vertical adjustment factor vo.o1
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45));
LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
    RainAtt=Att-LEN;
else
    RainAtt=Att;
end
oo=Ls-hypNon;
disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
    Lod=xn/(cosd(theta1));
    if Lod>Ls;
        Lod=Ls;
    else
        Lod=Lod;
    end
```

```
% LsNN=Ls-Lod;
%RAtt=LsNN*GamaR;
Lod22=RCS/cosd(theta1);
if Lod22>Ls
    Lod22=Ls;
else
    Lod22=Lod22;
end
Ls3=(Lod22)-Lod;

RAtt=Ls3*v001*GamaR;
disp(RAtt)
end
```

APPENDIX G: SUB-MATLAB PROGRAM TO PREDICT THE RAIN ATTENUATION FOR THE NON-STATIONARY SOURCES (SOUTH PART)

```
% FIRST STATION

f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
theta1=8.3244;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=126.1738;
GamaR=K*R001^alpha;
phi=3.682043;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
%Cloud speed assumed to be 5km/hr
Vcloud=(50/3600);%(5/3600):0.25:2.8; %velocity km/s
disCloud=Vcloud*t;
%Cloud velocity direction
dis2=dis-disCloud;
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
% horizontal reduction factor ro.o1
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
%the vertical adjustment factor vo.o1
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45));
LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
```

```
     RainAtt=Att-LEN;
else
     RainAtt=Att;
end

oo=Ls-hypNon;
disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
     Lod=xn/(cosd(theta1));
     if Lod>Ls;
         Lod=Ls;
     else
         Lod=Lod;
     end
    % LsNN=Ls-Lod;
    %RAtt=LsNN*GamaR;
    Lod22=RCS/cosd(theta1);
    if Lod22>Ls
        Lod22=Ls;
    else
        Lod22=Lod22;
    end
    Ls3=(Lod22)-Lod;
    RAtt=Ls3*v001*GamaR;
     disp(RAtt)
    end

% SECOND STATION

f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
theta1=11.8582;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=127.0600;
GamaR=K*R001^alpha;
phi=3.228569;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
%Cloud speed assumed to be 5km/hr
Vcloud=(50/3600);%(5/3600):0.25:2.8; %velocity km/s
disCloud=Vcloud*t;
%Cloud velocity direction
dis2=dis-disCloud;
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
```

```
LG=Ls.*cosd(theta1);
% horizontal reduction factor ro.ol
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
%the vertical adjustment factor vo.ol
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45));
LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
    RainAtt=Att-LEN;
else
    RainAtt=Att;
end
oo=Ls-hypNon;
disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
    Lod=xn/(cosd(theta1));
    if Lod>Ls;
        Lod=Ls;
    else
        Lod=Lod;
    End

   Lod22=RCS/cosd(theta1);
   if Lod22>Ls
       Lod22=Ls;
   else
       Lod22=Lod22;
   end
   Ls3=(Lod22)-Lod;
   RAtt=Ls3*v001*GamaR;
   disp(RAtt)
end

% THIRD STATION

f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
```

```
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
theta1=7.7126;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=128.9619;
GamaR=K*R001^alpha;
phi=2.648119;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
%Cloud speed assumed to be 5km/hr
Vcloud=(50/3600);%(5/3600):0.25:2.8; %velocity km/s
disCloud=Vcloud*t;
%Cloud velocity direction
dis2=dis-disCloud;
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
% horizontal reduction factor ro.ol
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
%the vertical adjustment factor vo.ol
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45));
LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
    RainAtt=Att-LEN;
else
    RainAtt=Att;
end
oo=Ls-hypNon;
disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
    Lod=xn/(cosd(theta1));
    if Lod>Ls;
        Lod=Ls;
    else
```

```
            Lod=Lod;
         end
        Lod22=RCS/cosd(theta1);
        if Lod22>Ls
            Lod22=Ls;
        else
            Lod22=Lod22;
        end
        Ls3=(Lod22)-Lod;
        RAtt=Ls3*v001*GamaR;
        disp(RAtt)
end

% FOURTH STATION
f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
theta1=8.0778;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=127.9571;
GamaR=K*R001^alpha;
phi=2.229204;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
Vcloud=(50/3600); s%Cloud speed assumed
disCloud=Vcloud*t;
dis2=dis-disCloud; %Cloud velocity direction
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
c=0.78.*sqrt(LG.*GamaR/f); % horizontal reduction factor ro.ol
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45)); %the vertical adjustment
factor vo.ol

LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
```

```
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
    RainAtt=Att-LEN;
else
    RainAtt=Att;
end
oo=Ls-hypNon;
disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
    Lod=xn/(cosd(theta1));
    if Lod>Ls;
        Lod=Ls;
    else
        Lod=Lod;
    end
   % LsNN=Ls-Lod;
   %RAtt=LsNN*GamaR;
   Lod22=RCS/cosd(theta1);
   if Lod22>Ls
       Lod22=Ls;
   else
       Lod22=Lod22;
   end
   Ls3=(Lod22)-Lod;
   RAtt=Ls3*v001*GamaR;
  disp(RAtt)
  end
% FIFTH STATION
f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
theta1=7.4445;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=126.4346;
GamaR=K*R001^alpha;
phi=2.227804;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
%Cloud speed assumed to be 5km/hr
Vcloud=(50/3600);%(5/3600):0.25:2.8; %velocity km/s
disCloud=Vcloud*t;
%Cloud velocity direction
dis2=dis-disCloud;
for LGN=dis2:dis2:RCS;
```

```
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
% horizontal reduction factor ro.o1
c=0.78.*sqrt(LG.*GamaR/f);
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
%the vertical adjustment factor vo.o1
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45));
LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
    RainAtt=Att-LEN;
else
    RainAtt=Att;
end
oo=Ls-hypNon;
disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
    Lod=xn/(cosd(theta1));
    if Lod>Ls;
        Lod=Ls;
    else
        Lod=Lod;
    end
   % LsNN=Ls-Lod;
   %RAtt=LsNN*GamaR;
   Lod22=RCS/cosd(theta1);
   if Lod22>Ls
       Lod22=Ls;
   else
       Lod22=Lod22;
   end
   Ls3=(Lod22)-Lod;
   RAtt=Ls3*v001*GamaR;
   disp(RAtt)
   end
```

APPENDIX H: SUB-MATLAB PROGRAM TO CALCULATE THE INTERSECTION TIMES FOR THE SIGNAL WITH THE RAIN (SATELLITE DIRECTION AGAINST CLOUDS)

```
RCS=1.25; %rain cell size
t=0.001; %time
Vsat=6.9; %satellite speed
for Vcloud=0:0.04:0.2;  %cloud speed
dis1=(Vsat*t)+(Vcloud*t); %Distance crossed at time of 0.001
SRInter=RCS/dis1; the number of the intersection between the cloud and
the signal
SRInterTotal=SRInterInteger*2; % the intersection of both sides of the
cloud
disp(SRInterTotal)
end
Vcloud1=0:0.04:0.2;
SRInterTotalAnswer=[362,360,358,356,354,352];
hold on
grid on
plot(Vcloud1,SRInterTotalAnswer)
xlabel('Cloud Velocity (km/s)')
ylabel('Chance of Signal Intersected the Rain')
```

APPENDIX I: SUB-MATLAB PROGRAM TO CALCULATE THE INTERSECTION TIMES FOR THE SIGNAL WITH THE RAIN (SATELLITE & CLOUDS IN SAME DIRECTION)

```
RCS=1.25;
t=0.001;
Vsat=6.9;
for Vcloud=0:0.04:0.2;
dis1=(Vsat*t)-(Vcloud*t);

SRInter=RCS/dis1;
SRInterInteger=int16(SRInter);
%The answer of the above equations, where each result must be times by
2
%because we need to calculate the Total signal length penetrated in the
rain for the two sides of the cloud 1.25*2
SRInterTotal=SRInterInteger*2;
disp(SRInterTotal)
end
Vcloud1=0:0.04:0.2;
SRInterTotalAnswer=[362,364,366,368,370,374];
hold on
grid on
plot(Vcloud1,SRInterTotalAnswer)
xlabel('Cloud Velocity (km/s)')
ylabel('Chance of Signal Intersected the Rain')
```

APPENDIX J: SUB-MATLAB PROGRAM TO CALCULATE THE EFFECTIVE CELL SIZE

```
ss=3;%satellite speed km/sec
cs=1;%cloud speed km/sec
RCS=4;%rain cell size
for d=0:0.1:0.5; %distance away from the rain cell edge
RCSE=ss+((ss/cs)*d);
if RCSE>RCS
    ERainSize=RCSE-(RCSE-RCS);
else
    ERainSize=RCSE;
end
disp(ERainSize)
end
```

APPENDIX K: SUB-MATLAB PROGRAM TO PREDICT THE RAIN ATTENUATION FOR THE NON-STATIONARY SOURCES USING CONVOLUTION METHOD

```
f=28;
hR=4.5;
hs=0.025;
h=25;
kH=0.2051;
alphaH=0.9679;
kV=0.1964;
alphaV=0.9277;
taw=45;
theta1=80;
K=(kH+kV+(kH-kV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2);
alpha=(kH*alphaH+kV*alphaV+(kH*alphaH-
kV*alphaV)*cosd(theta1)*cosd(theta1)*cosd(2*taw))/(2*K);
R001=110.2621;
GamaR=K*R001^alpha;
phi=2.751;
v=6.9; %satellite speed =3km/s
t=0.001; %time=0.001 second
dis=v*t;%distance of the horizontal projection penetrated in rain
RCS=1.25;%Rain cell size
Vcloud=(50/3600); %Cloud speed
disCloud=Vcloud*t;
dis2=dis-disCloud; %Cloud velocity direction
for LGN=dis2:dis2:RCS;
Ls=(hR-hs)/(sind(theta1));
LG=Ls.*cosd(theta1);
c=0.78.*sqrt(LG.*GamaR/f); % horizontal reduction factor ro.o1
d=0.38.*(1-exp(-2.*LG));
r001=1/(1+c-d);
%the vertical adjustment factor vo.o1
zeta=atand((hR-hs)/LG.*r001);
LR=(hR-hs)/sind(theta1);
chi=36-phi;
e=31.*(1-exp(-theta1/(1+chi)));
elf=sqrt(LR.*GamaR)/f.^2;
v001=1/(1+sqrt(sind(theta1)).*(e.*elf-0.45));
LE=LR*v001;
Att=GamaR*LE;
Lod9=LGN/cosd(theta1);
if Lod9>Ls
    Lodd=Ls;
else
    Lodd=Lod9;
end
hyp=((hR-hs)/sind(theta1));
hypNon=hyp-Lodd;
LEN=hypNon*v001*GamaR;
if LG>LGN
    RainAtt=Att-LEN;
```

```
else
    RainAtt=Att;
end
oo=Ls-hypNon;
%disp(RainAtt)
end
for xn=dis2:dis2:RCS %:LGNN
    Lod=xn/(cosd(theta1));
    if Lod>Ls;
        Lod=Ls;
    else
        Lod=Lod;
    end
   % LsNN=Ls-Lod;
   %RAtt=LsNN*GamaR;
   Lod22=RCS/cosd(theta1);
   if Lod22>Ls
       Lod22=Ls;
   else
       Lod22=Lod22;
   end
   Ls3=(Lod22)-Lod;
RAtt=Ls3*v001*GamaR;
end
%convolution
Aco=(dis2)/cosd(theta1); %signal part affected by rain at 0.001 s
Bco=RCS/cosd(theta1); % longest path will be affected by rain

for Cco=Aco:Aco:Bco; % limits of the signal parts will be affected by
rain
if Bco>Ls; % affected path length conditions
    Bco=Ls;
else
    Bco=Bco;
end
if Cco>Ls
    Cco=Ls;
else
    Cco=Cco;
end
Dco=GamaR*v001; % specific attenuation times reduction factor
Eco=[Dco];
Fco=conv(Cco,Eco); %convolution function to predict the attenuation
from the first time slot to the rain cell edge
disp(Fco)
end
for Gco=(Bco-Aco):-Aco:0; calculate the signal path length after
passing the rain cell edge
if Gco>Ls % signal path length condition
    Gco=Ls;
else
    Gco=Gco;
end
Hco=GamaR*v001; % specific attenuation times reduction factor
Ico=[Hco];
Jco=conv(Gco,Ico); %convolution function to predict the attenuation
```

```
after passing the rain cell edge till the end
disp(Jco)

end
```