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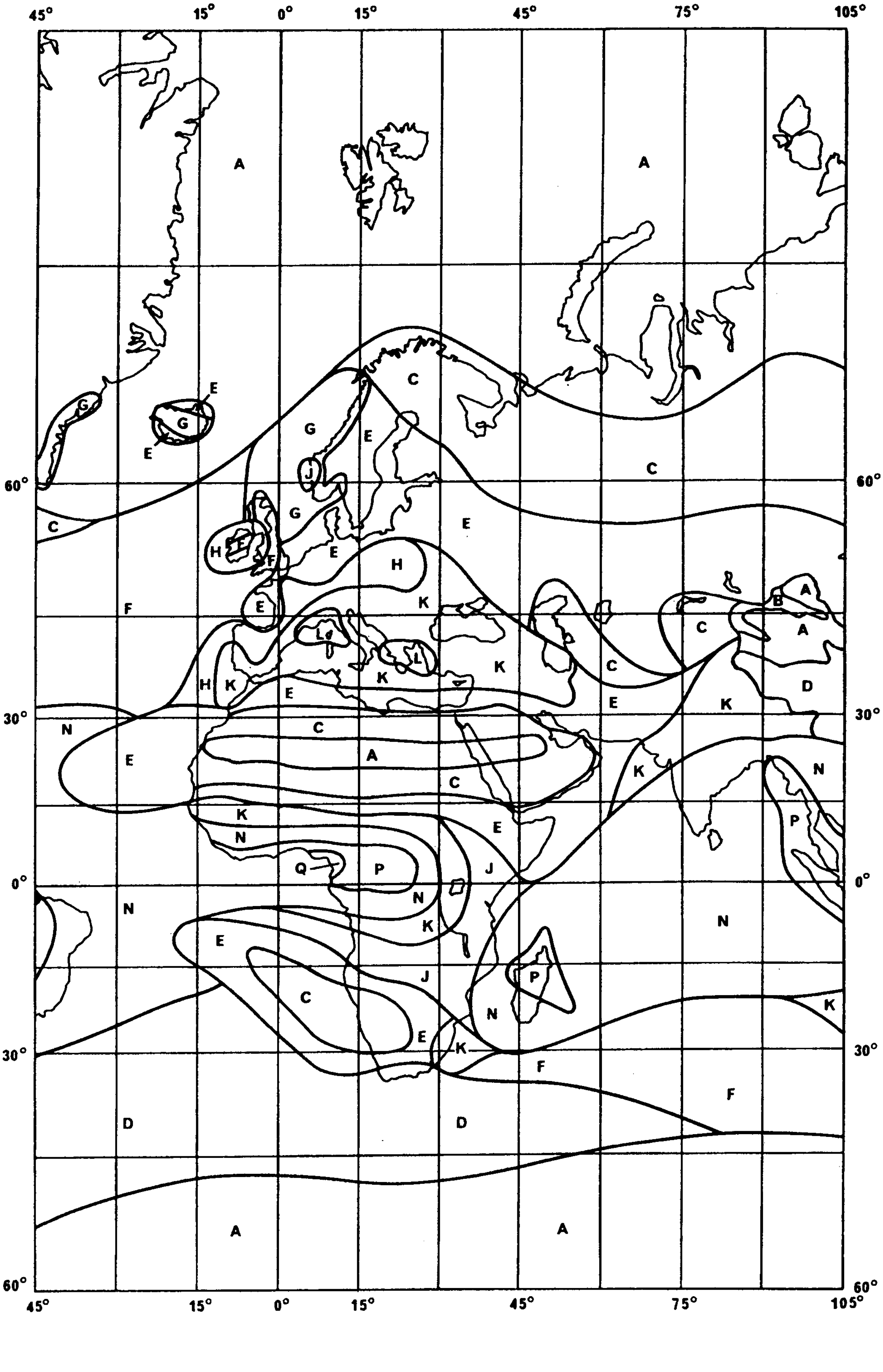
Appendix A

FIGURE 2

(See Table 1)



Appendix B

```
 Rain Fade Calculations
Drain in Km
YR in db/Km
Lrain in db

hrain=5;
hantenna=0.1;
e=[63.9;67.0;69.8;70.2;68.8;71.3;68.6;69.3;71.9;73.7;72.8;73.9;74.9;75.6;73
.1;76.5;76.3];
sin(e);
E=sin(e).*[1;-1;1;1;-1;1;-1;1;1;-1;-1;-1;-1;1;-1;1;1];
Drain=(hrain-hantenna)./E;

Rain Attenuations in 12GHZ (Horizontal)

   Availability 99%
K12h=0.0188;
alfa12h=1.217;
R1=[0.1;0.1;0.7;0.6;0.6;0.6;0.6;0.6;0.6;1.5;0.6;0.6;1.5;1.5;0.6;1.5;1.5];
YR1=K12h.*(R1.^alfa12h);
Lrain1=Drain.*YR1

   Availability 99.7%
R03=[0.8;0.8;2.8;2.4;2.4;2.4;2.4;2.4;2.4;4.2;2.4;2.4;4.2;4.2;2.4;4.2;4.2];
YR2=K12h.*(R03.^alfa12h);
Lrain2=Drain.*YR2

   Availability 99.9%
R01=[2;2;5;6;6;6;6;6;6;12;6;6;12;12;6;12;12];
YR3=K12h.*(R01.^alfa12h);
Lrain3=Drain.*YR3

Rain Attenuations in 12GHZ (vertical)
   Availability 99%
K12v=0.0168;
alfa12v=1.200;
YR4=K12v.*(R1.^alfa12v);
Lrain4=Drain.*YR4

   Availability 99.7%
YR5=K12v.*(R03.^alfa12v);
Lrain5=Drain.*YR5

   Availability 99.9%
YR6=K12v.*(R01.^alfa12v);
Lrain6=Drain.*YR6


Rain Attenuations in 20 GHZ (Horizontal)

  Availability 99%
K20h=0.0751;
alfa20h=1.099;
YR7=K20h.*(R1.^alfa20h);
Lrain7=Drain.*YR7
```

```
  Availability 99.7%
YR8=K20h.*(R03.^alfa20h);
Lrain8=Drain.*YR8

  Availability 99.9%
YR9=K20h.*(R01.^alfa20h);
Lrain9=Drain.*YR9
```

```
Rain Attenuation in 20 GHZ (Vertical)

  Availability 99%
K20v=0.0601;
alfa20v=1.065;
YR10=K20v.*(R1.^alfa20v);
Lrain10=Drain.*YR10

  Availability 99.7%
YR11=K20v.*(R03.^alfa20v);
Lrain11=Drain.*YR11

  Availability 99.9%
YR12=K20v.*(R01.^alfa20v);
Lrain12=Drain.*YR12
```

Compare the result between rain attenutinon at 12GH and 20GH

```
plot([Lrain6,Lrain12]
grid on
x=1:17;
set(gca, 'xtick',1:17, 'xticklabel',{'W-
hlfa','Dongla','Atbra','khartoum','N-hlfa','W-
madni','Kassla','Elgdarif','Sennar','Elgenina','Kosti','Elobied','Elnuhoud'
,'Nyala','Eldmazin','Babanusa','Kadugli'})
ylabel('Rain Attenuation in dB')
title('Rain Attenuation with availalbity 99.9% at 12GHZ and 20GHZ')
```

Compare the result between rain attenuation with availability 99.9% and *availability 99.7% and availability 99%*

```
plot([Lrain7,Lrain8,Lrain9])
grid on
x=1:17;
set(gca, 'xtick',1:17, 'xticklabel',{'W-
hlfa','Dongla','Atbra','khartoum','N-hlfa','W-
madni','Kassla','Elgdarif','Sennar','Elgenina','Kosti','Elobied','Elnuhoud'
,'Nyala','Eldmazin','Babanusa','Kadugli'})
```

```
ylabel('Rain Attenuation in dB')
title('Rain Attenuation with availalbity 99.9% & 99.7% & 99% at 20 GHZ')
```

Compare the result between rain attenuation at vertical polarization and horizontal polarization (12GH)

```
plot([Lrain6,Lrain12])
grid on
x=1:17;
set(gca, 'xtick',1:17, 'xticklabel',{'W-
hlfa','Dongla','Atbra','khartoum','N-hlfa','W-
madni','Kassla','Elgdarif','Sennar','Elgenina','Kosti','Elobied','Elnuhoud'
,'Nyala','Eldmazin','Babanusa','Kadugli'})
ylabel('Rain Attenuation in dB')
title('Rain Attenuation with availalbity 99.9% at 12GHZ and 20GHZ')
```

Compare the result between rain attenuation at vertical polarization and horizontal polarization (20GH)

```
f=20.*10^6;
c=3.*10^8;
lmda=c./f;
pi=22/7;
K=(2.*pi)./lmda;
beta=40;
theta=[0;20;40;60;80;100;120;140;160;180;200;220;240;260;280;300;320;340;36
0];
dmax=lmda./(1+sin(theta));
phi=(K.*dmax.*cos(theta))+beta;
N1=5;
AF1=(sin((N1.*phi)/2))./(sin(phi/2));
n1=[-1;1;1;1;-1;1;1;-1;1;-1;-1;-1;1;1;1;1;1;1;-1];
AFn1=(AF1.*n1)./N1
plot (theta,AFn1)
grid on
xlabel('theta [deg]')
ylabel('Array factor')
title('AF when N=5 &d=dmax')


N2=10;
AF2=(sin((N2.*phi)/2))./(sin(phi/2));
n2=[1;-1;1;-1;1;-1;1;1;1;1;1;-1;-1;1;1;-1;1;1;1];
AFn2= (AF2.*n2)./N2
plot(theta,AFn2)
grid on
xlabel('theta [deg]')
ylabel('Array Factor')
title('AF when N=10')

N3=20;
AF3=(sin((N3.*phi)/2))./(sin(phi/2));
n3=[1;-1;1;-1;-1;1;-1;-1;1;1;1;1;1;-1;-1;-1;-1;1;1;];
```

```
AFn3=(AF3.*n3)./N3
plot(theta,AFn3)
grid on
xlabel('theta [deg]')
ylabel('Array Factor')
title('AF when N=20 & d=dmax')

N4=60;
AF4=(sin((N4.*phi)/2))./(sin(phi/2));
n4=[1;1;1;-1;-1;1;1;-1;1;1;1;-1;1;1;-1;1;-1;-1;-1];
AFn4=(AF4.*n4)./N4
plot(theta,AFn4)
grid on
xlabel('theta [deg]')
ylabel('Array Factor')
title('AF when N=60 & d=dmax')
```

Array factors when d=dmax with variables Number of elements N=5,10,20&60

```
plot([AFn1,AFn2,AFn3,AFn4])
grid on
xlabel('theta [deg]')
ylabel('Array Factor')
legend('N=5','N=10','N=20','N=60')
title(' Array Factor when d=dmax')

d2=dmax/2;
phi2=(K.*d2.*cos(theta))+beta;
N1=5;
AF11=(sin((N1.*phi2)/2))./(sin(phi2/2));
n11=[-1;1;1;1;-1;1;1;-1;1;-1;-1;-1;1;1;1;1;1;1;-1];
AFn11=(AF1.*n11)./N1
plot (theta,AFn11)grid on
xlabel('theta [deg]')
ylabel('Array Factor')
title('AF when N=5 & d=dmax/2')

N2=10;
AF22=(sin((N2.*phi2)/2))./(sin(phi2/2));
n22=[1;1;-1;-1;1;-1;1;-1;1;1;1;1;1;-1;-1;-1;1;-1;1];
AFn22=(AF22.*n22)./N2
plot(theta,AFn22)
grid on
xlabel('theta [deg]')
ylabel('Array Factor')
title('AF when N=10 & d=dmax/2')

N3=20;
AF33=(sin((N3.*phi2)/2))./(sin(phi2/2));
n33=[-1;-1;-1;1;-1;-1;1;1;1;-1;-1;1;1;1;-1;1;1;-1;-1];
AFn33=(AF33.*n33)./N3
plot(theta,AFn33)
grid on
xlabel('theta [deg]')
ylabel('Array Factor')
title('AF when N=20 & d=dmax/2')
```

Array factors when d=dmax/2 with variables Number of elements N=5,10,20

```
plot([AFn11,AFn22,AFn33])
grid on
xlabel('theta [deg]')
ylabel('Array Factor')
legend('N=5','N=10','N=20')
title(' Array Factor when d=dmax/2')

d3=lmda/4; 2)
grid on
xlabel('theta [deg]')
ylabel('Array Factor')
title('AF when N=5 & d=dmax/
phi3=(K.*d3.*cos(theta))+beta;
N1=5;
AF12=(sin((N1.*phi3)/2))./(sin(phi3/2));
n12=[-1;1;1;1;-1;1;1;-1;1;-1;1;-1;1;1;1;-1;1;1;-1];
AFn12=(AF12.*n12)./N1
plot (theta,AFn14')
```

Ratio between wavelength and distance between individual elements Linear Array of N isotropic radiators

```
N    = 60;
alfa = -90:0.1:90;
d_l  = [0.1,0.5,1,2,5] ; % Ratio
for i=1:5
   Ed =abs(sin(N*pi*d_l(i)*sind(alfa))./sin(pi*d_l(i)*sind(alfa)))/N;
    fig = figure(i);
    set(fig,'Position', [100, 100, 1049, 400]);
    subplot(2,2,[1 3]);
    plot(alfa,Ed);
    grid on;
    axis([-90 90 0 1]);
    xlabel('Zenith angle [deg]');
    ylabel('Normalized radiation pattern');
    title(['Ratio between distance and wavelength d/\lambda =
',num2str(d_l(i))]);
    subplot(2,2,[2 4]);
    polar(alfa*pi/180,Ed);
    hold on;
    polar((alfa+180)*pi/180,Ed);
    xlabel(['Polar plot for the radiation pattern d/\lambda =
',num2str(d_l(i))]);
    hold off;
end
```

Distance between individual elements

```
f_EISCAT = 20.*10^6;
c = 3*10^8;           % Light Speed m/s
l = c/f_EISCAT;
d = [0.1,0.5,1,2,3];  % m
for i = 1:5
    % Normalizied gain
    Ed = abs(sin(N*pi*d(i)/l*sind(alfa))./sin(pi*d(i)/l*sind(alfa)))/N;
    % Ed - Array Factor, Radiation patern for isotropic radiators
    fig = figure(i+5);
    set(fig,'Position', [100, 100, 1049, 400]);
    subplot(2,2,[1 3]);
```

```
    plot(alfa,Ed);
    grid on;
    axis([-90 90 0 1]);
    xlabel('Zenith angle [deg]');
    ylabel('Normalized radiation pattern');
    title([' Distance between individual elements (space weighting) = ',...
        num2str(d (i)),' m,  F = 20Ghz']);
        subplot(2,2,[2 4]);
    polar(alfa*pi/180,Ed);
    hold on;
    polar((alfa+180)*pi/180,Ed);
    xlabel('Polar plot for the radiation pattern');
    hold off;
end
```

Number of antenna elements The distance between individual elements equals to the half wavelength of the signal

```
d_l = 0.5;
N   = [4 16 60 100 180];
for i = 1:5
    Ed = abs(sin(pi*d_l*N(i)*sind(alfa))./sin(pi*d_l*sind(alfa)))/N(i);
    fig = figure(i+10);
    set(fig,'Position', [100, 100, 1049, 400]);
    subplot(2,2,[1 3]);
    plot(alfa,Ed);
    grid on;
    axis([-90 90 0 1]);
    xlabel('Zenith angle [deg]');
    ylabel('Normalized array factor,Radiation pattern');
    title(['Number of elements = ',num2str(N(i)),', d/\lambda = 0.5']);
    subplot(2,2,[2 4]);
    polar(alfa*pi/180,Ed);
    hold on;
    polar((alfa+180)*pi/180,Ed);
    xlabel('Polar plot for the radiation pattern');
    hold off;
end
```

Radiation pattern change

```
N=60;
d_l = 0.5;
alfa0 = 30;
alN = 60;
fa = -180:0.1:180;
Ed = abs(sin(pi*d_l*N*(sind(alfa) - sind(alfa0) ))./...
                        sin(pi*d_l*(sind(alfa) - sind(alfa0))))/N;
Ed0 = abs(sin(pi*d_l*N*(sind(alfa)))./...
                        sin(pi*d_l*sind(alfa)))/N;
Edl = 20*log10(Ed);
Edl0= 20*log10(Ed0);
    fig = figure(16);
    set(fig,'Position', [100, 100, 1049, 400]);
    subplot(2,2,[1 3]);
    plot(alfa,Ed);
    hold on;
    plot(alfa,Ed0,'r');
    grid on;
    axis([-90 90 0 1]);
    xlabel('Zenith angle [deg]');

    ylabel('Normalized array factor,Radiation pattern');
    title(['Number of elements = ',num2str(N),', d/\lambda = 0.5']);
    legend('\beta = 30 deg','\beta = 0 deg','Location','NorthWest')
```

```
subplot(2,2,[2 4]);
polar(alfa*pi/180,Ed);
hold on;
polar(alfa*pi/180,Ed0,'r');
plot(alfa,Edl);
hold on;
xlabel('Polar plot for the radiation pattern');
hold off;
```