9 Anhang

9.1 Mathematik

Formeln, Operatoren jeweils in 3-dimensionalen kartesischen Koordinaten:

Nablaoperator

$$\nabla = \left(\frac{\partial}{\partial x} \cdot \overrightarrow{e_x} + \frac{\partial}{\partial y} \cdot \overrightarrow{e_y} + \frac{\partial}{\partial z} \cdot \overrightarrow{e_z}\right)$$

Laplace-Operator

$$\Delta = \nabla^2 = div(grad\ F) = \frac{\partial^2 F}{\partial x^2} + \frac{\partial^2 F}{\partial y^2} + \frac{\partial^2 F}{\partial z^2}$$

Gradient

$$grad\ F = \nabla \cdot F$$

Divergenz

$$div\ \vec{U} = \nabla \cdot \vec{U} = \frac{\partial U}{\partial x} + \frac{\partial U}{\partial y} + \frac{\partial U}{\partial z}$$

Rotation

$$rot\ \vec{U} = \nabla \times \vec{U} = \left(\frac{\partial U_z}{\partial y} - \frac{\partial U_y}{\partial z}\right) \cdot \overrightarrow{e_x} + \left(\frac{\partial U_x}{\partial z} - \frac{\partial U_z}{\partial x}\right) \cdot \overrightarrow{e_y} + \left(\frac{\partial U_y}{\partial x} - \frac{\partial U_x}{\partial y}\right) \cdot \overrightarrow{e_z}$$

Rotation der Rotation

$$\nabla \times (\nabla \times \vec{U}) = \nabla(\nabla \cdot \vec{U}) - \Delta \cdot \vec{U} = -\Delta\vec{U}$$

Integralsatz von Stokes

$$\oint \vec{U} \cdot \overrightarrow{ds} = \iint (\nabla \times \vec{U}) \cdot \overrightarrow{df}$$

Gaußscher Integralsatz

$$\oiint_F \vec{U} \cdot \overrightarrow{df} = \iiint_V \nabla \cdot \vec{U} \cdot dV$$

9.2 Maßeinheiten

Das SI (Système International d'Unités, Deutsch: „Internationales Einheitensystem“) wird häufig im Gegensatz zur 2er-Nomenklatur verwendet. Hiermit erklären wir die Unterschiede (siehe [38]):

A. Luntovskyy et al., *Planung und Optimierung von Rechnernetzen,* DOI 10.1007/978-3-8348-8242-4,

- Die Unterschiede bestehen darin, dass bei der physikalischen Nomenklatur SI-Präfixe mit 10er-Potenzen verwendet werden (Einheit = 10*10*10 = 1.000) und bei der 2er-Notation Binärpräfixe (Einheit = 2**10 = 1.024).
- Unterschied SI vs. 2er-Nomenklatur:

1 kB (Kilobyte)	= 10^3	~ 2^{10} Byte (Kibibyte; KiB/KB)	2,4 %
1 MB (Megabyte)	= 10^6	~ 2^{20} Byte (Mebibyte; MiB)	4,9 %
1 GB (Gigabyte)	= 10^9	~ 2^{30} Byte (Gibibyte; GiB)	7,4 %
1 TB (Terabyte)	= 10^{12}	~ 2^{40} Byte (Tebibyte; TiB)	10,0 %
1 PB (Petabyte)	= 10^{15}	~ 2^{50} Byte (Pebibyte; PiB)	12,6 %
1 EB (Exabyte)	= 10^{18}	~ 2^{60} Byte (Exbibyte; EiB)	15,3 %
1 ZB (Zettabyte)	= 10^{21}	~ 2^{70} Byte (Zebibyte; ZiB)	18,1 %
1 YB (Yottabyte)	= 10^{24}	~ 2^{80} Byte (Yobibyte; YiB)	20,9 %

9.3 MatLab-Skripte für Rechnernetzplanung

```
 %Program 1
 % Calculation of signal attenuation for different wave lengths
 %
d=1:0.1:1000;
lbd1=0.01; lbd2=0.025; lbd3=5.36e-2;
lbd4=0.1; lbd5=1.25e-1;
s1=(4*pi.*d/lbd1).^2;
s2=(4*pi.*d/lbd2).^2;
s3=(4*pi.*d/lbd3).^2;
s4=(4*pi.*d/lbd4).^2;
s5=(4*pi.*d/lbd5).^2;
g1=log10((4*pi.*d/lbd1).^2);
g2=log10((4*pi.*d/lbd2).^2);
g3=log10((4*pi.*d/lbd3).^2);
g4=log10((4*pi.*d/lbd4).^2);
g5=log10((4*pi.*d/lbd5).^2);
subplot (2,1,1);
plot (d,s1,'Color',[0,0,0],'Linewidth',2);
hold on;
plot (d,s2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot (d,s3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot (d,s4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
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```
plot (d,s5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('D, m','FontName', 'MS Sans Serif');
yl=ylabel ('Gamma, rel.','FontName', 'MS Sans Serif');
legend('lbd_0 = 1 cm', 'lbd_0 = 2.5 cm','lbd_0 = 5.36 cm',...
    'lbd_0 = 10 cm','lbd_0 = 12.5 cm');
subplot (2,1,2);
plot (d,g1,'Color',[0,0,0],'Linewidth',2);
hold on;
plot (d,g2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot (d,g3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot (d,g4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot (d,g5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('D, m','FontName', 'MS Sans Serif');
yl=ylabel ('Gamma, dB','FontName', 'MS Sans Serif');
legend('lbd_0 = 1 cm', 'lbd_0 = 2.5 cm','lbd_0 = 5.36 cm',...
    'lbd_0 = 10 cm','lbd_0 = 12.5 cm');
 %------------------------------------------------------------------
 %Program 2
 % Dependence of signal attenuation from the space angle Teta, to which
 % restricted the space of radio wave propagation
 %
d=50:0.1:1000;
lbd1=5.36e-2; lbd2=1.25e-1; lbd3=2.5e-1;
teta1=0.01; teta2=0.02; teta3=0.05; teta4=0.1; teta5=0.2;
g1=log10((teta1*d/lbd1).^2);
g2=log10((teta2*d/lbd1).^2);
g3=log10((teta3*d/lbd1).^2);
g4=log10((teta4*d/lbd1).^2);
g5=log10((teta5*d/lbd1).^2);
subplot(3,1,1)
plot (d,g1,'Color',[0,0,0],'Linewidth',2);
hold on;
plot (d,g2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot (d,g3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot (d,g4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot (d,g5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('D, m','FontName', 'MS Sans Serif');
yl=ylabel ('Gamma, dB','FontName', 'MS Sans Serif');
```

```
legend('teta = 0.01','teta=0.02','teta = 0.05','teta = 0.1',...
     'teta = 0.2','lbd = 0.0536 m');
f1=log10((teta1*d/lbd2).^2);
f2=log10((teta2*d/lbd2).^2);
f3=log10((teta3*d/lbd2).^2);
f4=log10((teta4*d/lbd2).^2);
f5=log10((teta5*d/lbd2).^2);
subplot(3,1,2)
plot (d,f1,'Color',[0,0,0],'Linewidth',2);
hold on;
plot (d,f2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot (d,f3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot (d,f4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot (d,f5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('D, m','FontName', 'MS Sans Serif');
yl=ylabel ('Gamma, dB','FontName', 'MS Sans Serif');
legend('teta = 0.01','teta=0.02','teta = 0.05','teta = 0.1',...
            'teta = 0.2','lbd = 0.125 m');
w1=log10((teta1*d/lbd3).^2);
w2=log10((teta2*d/lbd3).^2);
w3=log10((teta3*d/lbd3).^2);
w4=log10((teta4*d/lbd3).^2);
w5=log10((teta5*d/lbd3).^2);
subplot(3,1,3)
plot (d,w1,'Color',[0,0,0],'Linewidth',2);
hold on;
plot (d,w2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot (d,w3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot (d,w4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot (d,w5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('D, m','FontName', 'MS Sans Serif');
yl=ylabel ('Gamma, dB','FontName', 'MS Sans Serif');
legend('teta = 0.01','teta=0.02','teta = 0.05','teta = 0.1',...
'teta = 0.2','lbd = 0.25 m');
 %-------------------------------------------------------------------
 %Program 3
 % Dependence of parameters of wireless access point position from
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```
 % the building geometry for one-wall reflection model
 %
R=5:1:100; rd=1.2;
h1=2; h2=2.5; h3=3; h4=4; h5=5;
a1=2*h1*rd./R; a2=2*h2*rd./R;
a3=2*h3*rd./R; a4=2*h4*rd./R;
a5=2*h5*rd./R;
b1=pi/2-atan(R./(2*h1)); b2=pi/2-atan(R./(2*h2));
b3=pi/2-atan(R./(2*h3)); b4=pi/2-atan(R./(2*h4));
b5=pi/2-atan(R./(2*h5));
subplot (2,1,1);
plot(R,a1,'Color',[0,0,0],'Linewidth',2); hold on;
plot(R,a2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(R,a3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(R,a4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot(R,a5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('R, m','FontName', 'MS Sans Serif');
yl=ylabel ('a, m','FontName', 'MS Sans Serif');
legend('h = 2 m','h = 2.5 m','h = 3 m','h = 4 m',...
'h = 5 m','r = 1.2 m');
subplot (2,1,2);
plot(R,b1,'Color',[0,0,0],'Linewidth',2); hold on;
plot(R,b2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(R,b3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(R,b4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot(R,b5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('R, m','FontName', 'MS Sans Serif');
yl=ylabel ('beta, rad','FontName', 'MS Sans Serif');
legend('h = 2 m','h = 2.5 m','h = 3 m','h = 4 m','h = 5 m',...
'r = 1.2 m');
 %-------------------------------------------------------------------
 %Program 4
 % Dependence of wireless access point antenna direction angle
 % (antenna downtilt) from building geometry
 % for multi-wall reflection model, n = 2, k = 3.
 %
n=2; k=3; h1=3; h2=2;
R1=10:0.1:50;
R21=20; R22=30;
```

```
R23=40; R24=50;
R25=60;
a1=atan((R21+2*h1*(n+1))./(R1+2*h2*(k+1)));
a2=atan((R22+2*h1*(n+1))./(R1+2*h2*(k+1)));
a3=atan((R23+2*h1*(n+1))./(R1+2*h2*(k+1)));
a4=atan((R24+2*h1*(n+1))./(R1+2*h2*(k+1)));
a5=atan((R25+2*h1*(n+1))./(R1+2*h2*(k+1)));
plot(R1,a1,'Color',[0,0,0],'Linewidth',2); hold on;
plot(R1,a2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(R1,a3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(R1,a4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot(R1,a5,'Color',[0,0,0],'Linewidth',3);
grid on;
xl=xlabel ('R, m','FontName', 'MS Sans Serif');
yl=ylabel ('alfa, rad','FontName', 'MS Sans Serif');
legend('R_2 = 20 m','R_2 = 30 m','R_2 = 40 m','R_2 = 50 m',...
'R_2 = 60 m','h_1 = 3 m', 'h_2 = 2 m');
 %------------------------------------------------------------------
 %Program 5
 % Calculation of maximum distance of signal transmitting in
 % dependence on the height of transmitting and receiving antennas
 %
ha1=50; ha2=100; ha3=150; ha4=200; ha5=250;
h2=5:0.1:500;
l1=4.12.*(sqrt(ha1)+sqrt(h2));
l2=4.12.*(sqrt(ha2)+sqrt(h2));
l3=4.12.*(sqrt(ha3)+sqrt(h2));
l4=4.12.*(sqrt(ha4)+sqrt(h2));
l5=4.12.*(sqrt(ha5)+sqrt(h2));
plot(h2,l1,'Color',[0,0,0],'Linewidth',2);
hold on;
plot (h2,l2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot (h2,l3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot (h2,l4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot (h2,l5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('h_2, m','FontName', 'MS Sans Serif');
yl=ylabel ('L, km','FontName', 'MS Sans Serif');
legend('h_a = 50 m','h_a = 100 m','h_a = 150 m',...
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```
            'h_a = 200 m','h_a = 250 m');
 %----------------------------------------------------------------------
 %Program 6
 % Calculation of radius of first Fresnel diffraction zone ⊠0.
 % Here D - distance between antennas
 %
d1=10:0.1:500; D=550; d2=D-d1;
lbd1=0.02; lbd2=5.36e-2; lbd3=0.1;
lbd4=1.25e-1; lbd5=2.5e-1;
H1=sqrt(d1.*d2.*lbd1./(d1+d2));
H2=sqrt(d1.*d2.*lbd2./(d1+d2));
H3=sqrt(d1.*d2.*lbd3./(d1+d2));
H4=sqrt(d1.*d2.*lbd4./(d1+d2));
H5=sqrt(d1.*d2.*lbd5./(d1+d2));
subplot (4,1,1);
plot(d1*1e-3,H1,'Color',[0,0,0],'Linewidth',2); hold on;
plot(d1*1e-3,H2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(d1*1e-3,H3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(d1*1e-3,H4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot(d1*1e-3,H5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('d_1, km','FontName', 'MS Sans Serif');
yl=ylabel ('H_0, m','FontName', 'MS Sans Serif');
legend('lbd_0 = 2 cm','lbd_0 = 5.36 cm','lbd_0 = 10 cm','lbd_0 = ... 12.5
cm','lbd_0 = 25 cm','D = 550 m');
subplot (4,1,2); D=600; d3=D-d1;
H1=sqrt(d1.*d3.*lbd1./(d1+d3));
H2=sqrt(d1.*d3.*lbd2./(d1+d3));
H3=sqrt(d1.*d3.*lbd3./(d1+d3));
H4=sqrt(d1.*d3.*lbd4./(d1+d3));
H5=sqrt(d1.*d3.*lbd5./(d1+d3));
plot(d1*1e-3,H1,'Color',[0,0,0],'Linewidth',2); hold on;
plot(d1*1e-3,H2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(d1*1e-3,H3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');d1*1e-
3,H4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot(d1*1e-3,H5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('d_1, km','FontName', 'MS Sans Serif');
yl=ylabel ('H_0, m','FontName', 'MS Sans Serif');
legend('lbd_0 = 2 cm','lbd_0 = 5.36 cm','lbd_0 = 10 cm',...
 'lbd_0 = 12.5 cm','lbd_0 = 25 cm','D = 600 m');
```

```
subplot (4,1,3); D=700; d4=D-d1;
H1=sqrt(d1.*d4.*lbd1./(d1+d4));
H2=sqrt(d1.*d4.*lbd2./(d1+d4));
H3=sqrt(d1.*d4.*lbd3./(d1+d4));
H4=sqrt(d1.*d4.*lbd4./(d1+d4));
H5=sqrt(d1.*d4.*lbd5./(d1+d4));
plot(d1*1e-3,H1,'Color',[0,0,0],'Linewidth',2); hold on;
plot(d1*1e-3,H2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(d1*1e-3,H3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(d1*1e-3,H4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot(d1*1e-3,H5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('d_1, km','FontName', 'MS Sans Serif');
yl=ylabel ('H_0, m','FontName', 'MS Sans Serif');
legend('lbd_0 = 2 cm','lbd_0 = 5.36 cm','lbd_0 = 10 cm',...
 'lbd_0 = 12.5 cm','lbd_0 = 25 cm','D = 700 m');
subplot (4,1,4); D=1000; d5=D-d1;
H1=sqrt(d1.*d5.*lbd1./(d1+d5));
H2=sqrt(d1.*d5.*lbd2./(d1+d5));
H3=sqrt(d1.*d5.*lbd3./(d1+d5));
H4=sqrt(d1.*d5.*lbd4./(d1+d5));
H5=sqrt(d1.*d5.*lbd5./(d1+d5));
plot(d1*1e-3,H1,'Color',[0,0,0],'Linewidth',2); hold on;
plot(d1*1e-3,H2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(d1*1e-3,H3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(d1*1e-3,H4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot(d1*1e-3,H5,'Color',[0,0,0],'Linewidth',3,'Linestyle','-');
grid on;
xl=xlabel ('d_1, km','FontName', 'MS Sans Serif');
yl=ylabel ('H_0, m','FontName', 'MS Sans Serif');
legend('lbd_0 = 2 cm','lbd_0 = 5.36 cm','lbd_0 = 10 cm',...
 'lbd_0 = 12.5 cm','lbd_0 = 25 cm','D = 1000 m');
 %------------------------------------------------------------------
 %Program 7
 % Calculation of diffraction at the wedge-like obstacle for different
 % geometry of information transmitting systems
 %
d11=100; d12=200;
d21=200; d22=300;
```

```
d31=300; d32=500;
d41=500; d42=600;
h=-2:0.1:15;
lbd1=5.36e-2; lbd2=1.25e-1; lbd3=1;
nu11=h.*sqrt(2*(d11+d12)/lbd1/d11/d12);
J11=6.9.*20.*log(nu11-0.1+((nu11-0.1).^2+1).^(0.5))/10;
nu12=h.*sqrt(2*(d21+d22)/lbd1/d21/d22);
J12=6.9.*20.*log(nu12-0.1+((nu12-0.1).^2+1).^(0.5))/10;
nu13=h.*sqrt(2*(d31+d32)/lbd1/d31/d32);
J13=6.9.*20.*log(nu13-0.1+((nu13-0.1).^2+1).^(0.5))/10;
nu14=h.*sqrt(2*(d41+d42)/lbd1/d41/d42);
J14=6.9.*20.*log(nu14-0.1+((nu14-0.1).^2+1).^(0.5))/10;
subplot (3,1,1);
plot(h,J11,'Color',[0,0,0],'Linewidth',2); hold on;
plot(h,J12,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(h,J13,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(h,J14,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
grid on;
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('J(h), dB','FontName', 'MS Sans Serif');
legend('d1 = 100 m; d2 = 200 m','d1 = 200 m; d2 = 300 m',...
 'd1 = 300 m; d2 = 500 m','d1 = 500 m; d2 = 600 m',...
 'lbd_0 = 5.36 cm');
nu21=h.*sqrt(2*(d11+d12)/lbd2/d11/d12);
J21=6.9.*20.*log(nu21-0.1+((nu21-0.1).^2+1).^(0.5))/10;
nu22=h.*sqrt(2*(d21+d22)/lbd2/d21/d22);
J22=6.9.*20.*log(nu22-0.1+((nu22-0.1).^2+1).^(0.5))/10;
nu23=h.*sqrt(2*(d31+d32)/lbd2/d31/d32);
J23=6.9.*20.*log(nu23-0.1+((nu23-0.1).^2+1).^(0.5))/10;
nu24=h.*sqrt(2*(d41+d42)/lbd2/d41/d42);
J24=6.9.*20.*log(nu24-0.1+((nu24-0.1).^2+1).^(0.5))/10;
subplot (3,1,2);
plot(h,J21,'Color',[0,0,0],'Linewidth',2); hold on;
plot(h,J22,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(h,J23,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(h,J24,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
grid on;
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('J(h), dB','FontName', 'MS Sans Serif');
legend('d1 = 100 m; d2 = 200 m','d1 = 200 m; d2 = 300 m',...
 'd1 = 300 m; d2 = 500 m','d1 = 500 m; d2 = 600 m',...
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```
     'lbd_0 = 12.5 cm');
nu31=h.*sqrt(2*(d11+d12)/lbd3/d11/d12);
J31=6.9.*20.*log(nu31-0.1+((nu31-0.1).^2+1).^(0.5))/10;
nu32=h.*sqrt(2*(d21+d22)/lbd3/d21/d22);
J32=6.9.*20.*log(nu32-0.1+((nu32-0.1).^2+1).^(0.5))/10;
nu33=h.*sqrt(2*(d31+d32)/lbd3/d31/d32);
J33=6.9.*20.*log(nu33-0.1+((nu33-0.1).^2+1).^(0.5))/10;
nu34=h.*sqrt(2*(d41+d42)/lbd3/d41/d42);
J34=6.9.*20.*log(nu34-0.1+((nu34-0.1).^2+1).^(0.5))/10;
subplot (3,1,3);
plot(h,J31,'Color',[0,0,0],'Linewidth',2); hold on;
plot(h,J32,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(h,J33,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(h,J34,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
grid on;
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('J(h), dB','FontName', 'MS Sans Serif');
legend('d1 = 100 m; d2 = 200 m','d1 = 200 m; d2 = 300 m',...
 'd1 = 300 m; d2 = 500 m','d1 = 500 m; d2 = 600 m',...
     'lbd_0 = 10 m');
 %--------------------------------------------------------------------
 %Program 8
 % Calculations of straight sight zone for sphere, which size is
 % similar to height of transmitting and receiving antennas
 %
h1=100; h2=10:1:300;
R1=20; R2=50; R3=100;
R4=150; R5=200; R6=300;
R7=400; R8=500;
L1=sqrt((R1+h1).^2-R1^2)+sqrt((R1+h2).^2-R1^2);
L2=sqrt((R2+h1).^2-R2^2)+sqrt((R2+h2).^2-R2^2);
L3=sqrt((R3+h1).^2-R3^2)+sqrt((R3+h2).^2-R3^2);
L4=sqrt((R4+h1).^2-R4^2)+sqrt((R4+h2).^2-R4^2);
L5=sqrt((R5+h1).^2-R5^2)+sqrt((R5+h2).^2-R5^2);
L6=sqrt((R6+h1).^2-R6^2)+sqrt((R6+h2).^2-R6^2);
L7=sqrt((R7+h1).^2-R7^2)+sqrt((R7+h2).^2-R7^2);
L8=sqrt((R8+h1).^2-R8^2)+sqrt((R8+h2).^2-R8^2);
plot(h2,L1,'Color',[0,0,0],'Linewidth',2);
hold on;
```

```
plot (h2,L2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot (h2,L3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot (h2,L4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
plot (h2,L5,'Color',[0,0,0],'Linewidth',3);
plot (h2,L6,'Color',[0,0,0],'Linewidth',3,'Linestyle','--');
plot (h2,L7,'Color',[0,0,0],'Linewidth',3,'Linestyle','-.');
plot (h2,L8,'Color',[0,0,0],'Linewidth',3,'Linestyle',':');
grid on;
xl=xlabel ('h_2, m','FontName', 'MS Sans Serif');
yl=ylabel ('L, km','FontName', 'MS Sans Serif');
legend('R = 20 m','R = 50 m','R = 100 m','R = 150 m',...
    'R = 200 m','R = 300 m','R = 400 m','R = 500 m');
 %-------------------------------------------------------------------
 %Program 9
 % Calculation of attenuation coefficient for diffraction on the sphere
for
 % different geometry parameters of transmitting-receiving system
d11=0.1; d12=0.2; R1=500;
d21=0.2; d22=0.3; R2=700;
d31=0.3; d32=0.5; R3=1000;
h=0.1:0.1:25;
lbd1=5.36e-2; lbd2=1.25e-1; lbd3=500;
nu11=0.0316*h.*sqrt(2*(d11+d12)/lbd1/d11/d12);
J11=6.9.*20.*log(nu11-0.1+((nu11-0.1).^2+1).^(0.5))/10;
M11=R1.*((d11+d12)/d11/d12).*((pi*R1/lbd1).^(-1/3));
N11=R1./h.*((pi*R1/lbd1).^(2/3)); K11=8.2+12.*N11;
B11=0.73+0.27.*(1-exp(-1.43*N11));
T11=K11.*M11.^B11; A11=40-log(J11+T11);
nu12=0.0316*h.*sqrt(2*(d21+d22)/lbd1/d21/d22);
J12=6.9.*20.*log(nu12-0.1+((nu12-0.1).^2+1).^(0.5))/10;
M12=R2.*((d21+d22)/d21/d22).*((pi*R2/lbd1).^(-1/3));
N12=R2./h.*((pi*R2/lbd1).^(2/3)); K12=8.2+12.*N12;
B12=0.73+0.27.*(1-exp(-1.43*N12));
T12=K12.*M12.^B12; A12=40-log(J12+T12);
nu13=0.0316*h.*sqrt(2*(d31+d32)/lbd1/d31/d32);
J13=6.9.*20.*log(nu13-0.1+((nu13-0.1).^2+1).^(0.5))/10;
M13=R3.*((d31+d32)/d31/d32).*((pi*R3/lbd1).^(-1/3));
N13=R3./h.*((pi*R3/lbd1).^(2/3)); K13=8.2+12.*N13;
B13=0.73+0.27.*(1-exp(-1.43*N13));
T13=K13.*M13.^B13; A13=40-log(J13+T13);
subplot (3,1,1);
```

```
plot(h,A11,'Color',[0,0,0],'Linewidth',2); hold on;
plot(h,A12,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(h,A13,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
grid on;
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('A(h), dB','FontName', 'MS Sans Serif');
legend('d_1 = 100 m, d_2 = 200 m, R = 500 m;',...
 'd_1 = 200 m, d_2 = 300 m, R = 700 m;',...
 'd_1 = 300 m, d_2 = 500 m, R = 1 km;',...
 'lbd_0 = 5.36 cm');
nu21=0.0316*h.*sqrt(2*(d11+d12)/lbd2/d11/d12);
J21=6.9.*20.*log(nu21-0.1+((nu21-0.1).^2+1).^(0.5))/10;
M21=R1.*((d11+d12)/d11/d12).*((pi*R1/lbd2).^(-1/3));
N21=R1./h.*((pi*R1/lbd2).^(2/3)); K21=8.2+12.*N21;
B21=0.73+0.27.*(1-exp(-1.43*N21));
T21=K21.*M21.^B21; A21=40-log(J21+T21);
nu22=0.0316*h.*sqrt(2*(d21+d22)/lbd2/d21/d22);
J22=6.9.*20.*log(nu22-0.1+((nu22-0.1).^2+1).^(0.5))/10;
M22=R2.*((d21+d22)/d21/d22).*((pi*R2/lbd2).^(-1/3));
N22=R2./h.*((pi*R2/lbd2).^(2/3)); K22=8.2+12.*N22;
B22=0.73+0.27.*(1-exp(-1.43*N22));
T22=K22.*M22.^B22; A22=40-log(J22+T22);
nu23=0.0316*h.*sqrt(2*(d31+d32)/lbd2/d31/d32);
J23=6.9.*20.*log(nu23-0.1+((nu23-0.1).^2+1).^(0.5))/10;
M23=R3.*((d31+d32)/d31/d32).*((pi*R3/lbd2).^(-1/3));
N23=R3./h.*((pi*R3/lbd2).^(2/3)); K23=8.2+12.*N23;
B23=0.73+0.27.*(1-exp(-1.43*N23));
T23=K23.*M23.^B23; A23=40-log(J23+T23);
subplot (3,1,2);
plot(h,A21,'Color',[0,0,0],'Linewidth',2); hold on;
plot(h,A22,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(h,A23,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
grid on;
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('A(h), dB','FontName', 'MS Sans Serif');
legend('d_1 = 100 m, d_2 = 200 m, R = 500 m;',...
 'd_1 = 200 m, d_2 = 300 m, R = 700 m;',...
 'd_1 = 300 m, d_2 = 500 m, R = 1 km;','lbd_0 = 12.5 cm');
nu31=0.0316*h.*sqrt(2*(d11+d12)/lbd3/d11/d12);
```

```
J31=6.9.*20.*log(nu31-0.1+((nu31-0.1).^2+1).^(0.5))/10;
M31=R1.*((d11+d12)/d11/d12).*((pi*R1/lbd3).^(-1/3));
N31=R1./h.*((pi*R1/lbd3).^(2/3)); K31=8.2+12.*N31;
B31=0.73+0.27.*(1-exp(-1.43*N31));
T31=K31.*M31.^B31; A31=30-log(J31+T31);
nu32=0.0316*h.*sqrt(2*(d21+d22)/lbd3/d21/d22);
J32=6.9.*20.*log(nu32-0.1+((nu32-0.1).^2+1).^(0.5))/10;
M32=R2.*((d21+d22)/d21/d22).*((pi*R2/lbd3).^(-1/3));
N32=R2./h.*((pi*R2/lbd3).^(2/3)); K32=8.2+12.*N32;
B32=0.73+0.27.*(1-exp(-1.43*N22));
T32=K32.*M32.^B32; A32=30-log(J32+T32);
nu33=0.0316*h.*sqrt(2*(d31+d32)/lbd3/d31/d32);
J33=6.9.*20.*log(nu33-0.1+((nu33-0.1).^2+1).^(0.5))/10;
M33=R3.*((d31+d32)/d31/d32).*((pi*R3/lbd3).^(-1/3));
N33=R3./h.*((pi*R3/lbd3).^(2/3)); K33=8.2+12.*N33;
B33=0.73+0.27.*(1-exp(-1.43*N33));
T33=K33.*M33.^B33; A33=30-log(J33+T33);
subplot (3,1,3);
plot(h,A31,'Color',[0,0,0],'Linewidth',2); hold on;
plot(h,A32,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(h,A33,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
grid on;
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('A(h), dB','FontName', 'MS Sans Serif');
legend('d_1 = 100 m, d_2 = 200 m, R = 500 m;',...
 'd_1 = 200 m, d_2 = 300 m, R = 700 m;',...
 'd_1 = 300 m, d_2 = 500 m, R = 1 km;','lbd_0 = 500 m');
 %-------------------------------------------------------------------
 %Program 10
 % 1. Calculation of the dependences of effective radius of Earth surface
 % and effective dielectric capacity from height of radio channel
 % 2. Calculation of the dependences of normalized coefficients of sur-
face
 % conductivity from the highness of transmitting and receiver antennas
 % 3. Calculation of the dependences of radio waves attenuation coeffi-
cient % in atmosphere from the height for different length of radio chan-
nel
Main function
 %Main function
function inferth
hx=1:1:1000; fs=1000;
cx=ae(300,1500,500,0.0015,0.105,0.105,hx);
```

```
subplot (2,1,1);
plot(hx,cx(1,:),'Color',[0,0,0],'Linewidth',2); grid on;
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('R_E(h), km','FontName', 'MS Sans Serif');
subplot (2,1,2);
plot(hx,cx(2,:),'Color',[0,0,0],'Linewidth',2); grid on;
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('eps(h)','FontName', 'MS Sans Serif');
figure
subplot (2,1,1);
dx=kvh(cx(1,:),cx(2,:),fs,0.001);
plot(hx,dx(1,:),'Color',[0,0,0],'Linewidth',2);
grid on; hold on;
plot(hx,dx(2,:),'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('K_H(h), K_V(h), dB','FontName', 'MS Sans Serif');
legend ('K_H(h)','K_V(h)');
subplot (2,1,2);
plot(hx,dx(3,:),'Color',[0,0,0],'Linewidth',2); grid on;
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('K(h), dB','FontName', 'MS Sans Serif');
bch=1+1.6.*(dx(3,:)).^2+0.75.*(dx(3,:)).^4;
bzn=1+4.5.*(dx(3,:)).^2+1.35.*(dx(3,:)).^4;
beta=bch./bzn;
ky=dx(3,:); Re=cx(1,:);
mn=(fs./Re./Re).^1/3;
d1=0.1; d2=1; d3=10; d4=50;
X1=2.2.*beta.*d1.*mn;
X2=2.2.*beta.*d2.*mn;
X3=2.2.*beta.*d3.*mn;
X4=2.2.*beta.*d4.*mn;
F1=11+10.*log(X1)-1.76.*X1;
F2=11+10.*log(X2)-1.76.*X2;
F3=11+10.*log(X3)-1.76.*X3;
F4=11+10.*log(X4)-1.76.*X4;
mn2=(fs.*fs./Re).^1/3;
Ya=9.6e-3.*beta.*hx.*mn2;
G=17.6.*sqrt(Ya-1.1)-5.*log(Ya-1.1)-8;
RT1=(F1+2.*G)/20; RT2=(F2+2.*G)/20;
```

```
RT3=(F3+2.*G)/20; RT4=(F4+2.*G)/20;
figure
plot(hx,RT1,'Color',[0,0,0],'Linewidth',2);
hold on; grid on;
plot(hx,RT2,'Color',[0,0,0],'Linewidth',2,'Linestyle',':');
plot(hx,RT3,'Color',[0,0,0],'Linewidth',2,'Linestyle','--');
plot(hx,RT4,'Color',[0,0,0],'Linewidth',2,'Linestyle','-.');
xl=xlabel ('h, m','FontName', 'MS Sans Serif');
yl=ylabel ('lg(E/E_0), dB','FontName', 'MS Sans Serif');
legend('d = 100 m;','d = 1 km;','d = 10 km;', 'd = 50 km');
return
Function for calculation effective radius of Earth surface and effective
dielectric capacity
 % Calculation effective radius of Earth surface and effective
 % dielectric capacity
 %
function outxy=ae(T0,p0,pn0,k1,k2,k3,h);
T=T0-k1.*h;p=p0-k2.*h; pn=pn0-k3.*h;
dedh1=(1.552e-4*(k2*T+k1*p))./T.^2;
dedh2=((0.7465.*k3.*h.*T.^2)+(1.4393.*k1.*(k1.*h-1).*pn))./(T.^4);
dedh=dedh1-dedh2;
aez=6400./(1+320.*dedh);
eps=1+(1.552e-4./T).*(p+(4810.*pn)./T);
outxy=[aez;eps];
return
Function for calculation of normalized coefficients of surface conductiv-
ity
 % Calculation of normalized coefficients of surface conductivity
 %
function outxy=kvh(aek,epsk,fk,sigmak);
ZKH1=(aek.*fk).^(1/3);
ZKH2=(epsk-1).^2;
ZKH3=(18000.*sigmak./fk).^2;
ZKH=ZKH1.*(ZKH3-ZKH2).^0.25;
KH=0.36./ZKH;
ZKV=sqrt(epsk.^2+ZKH3);
KV=KH./ZKV;
K=sqrt(KV.^2+KH.^2);
outxy=[KH;KV;K];
return
```

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