MCS

MCS Lab 1 Report

SAKKA MOHAMAD-MARIO
EL-GHOUL LAYLA
MAHMOUD MIRGHANI ABDELRAHMAN

1. PLOTS RESULTING FROM CODE

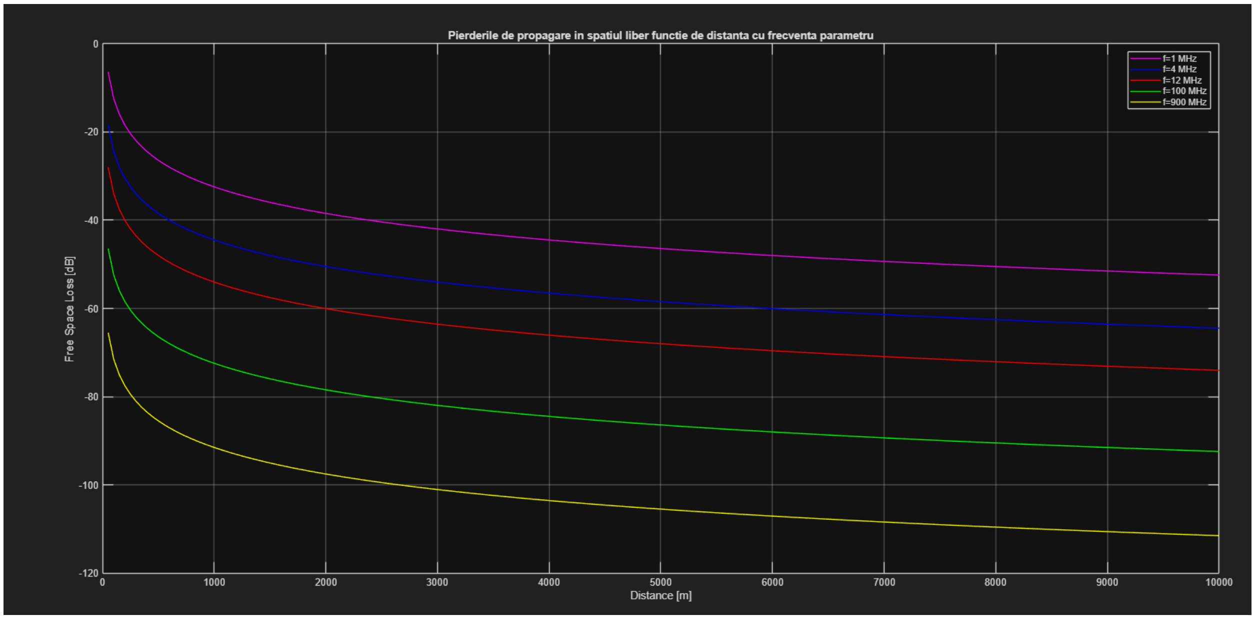


Figure 1: Plot of free space propagation loss as a function of distance with frequency as a parameter

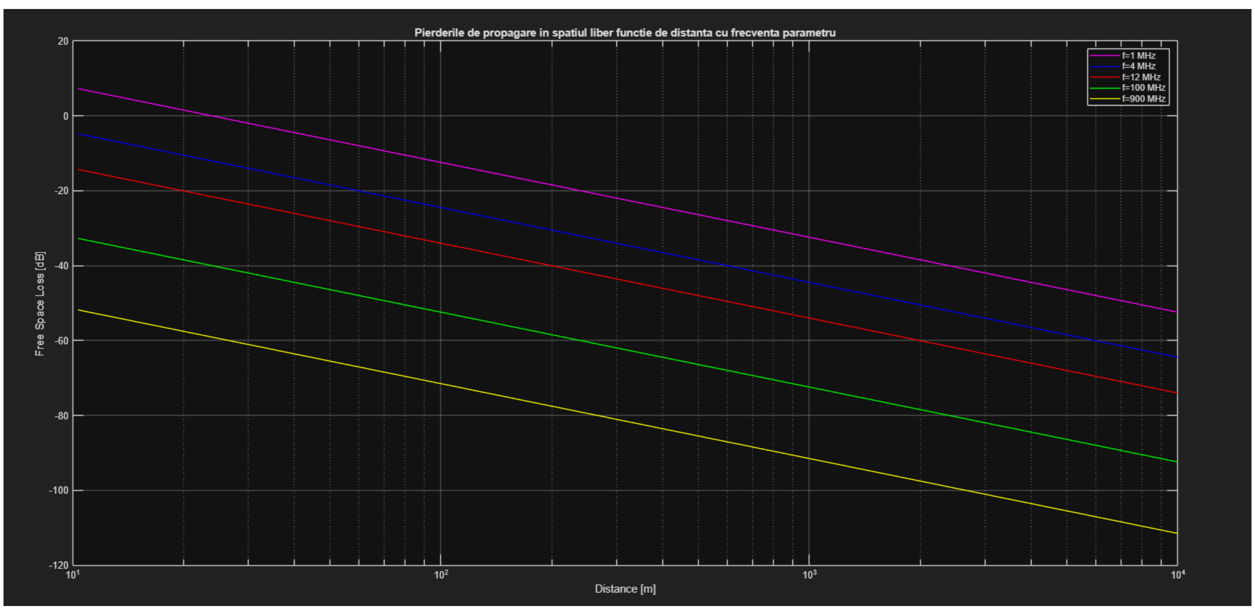


Figure 2: Plot of free space propagation loss as a function of distance with frequency as a parameter, using a logarithmic scale for distance.

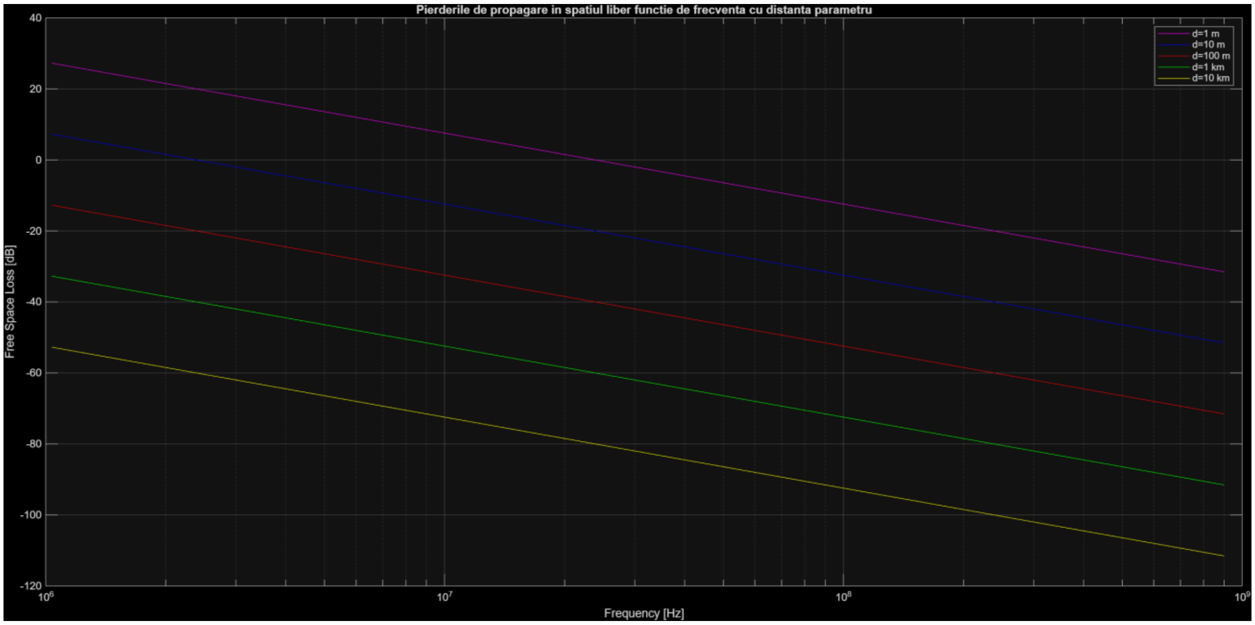


Figure 3: Plot of free space propagation loss as a function of frequency with distance as a parameter, using a logarithmic scale for frequency.

2. ANSWERING QUESTIONS

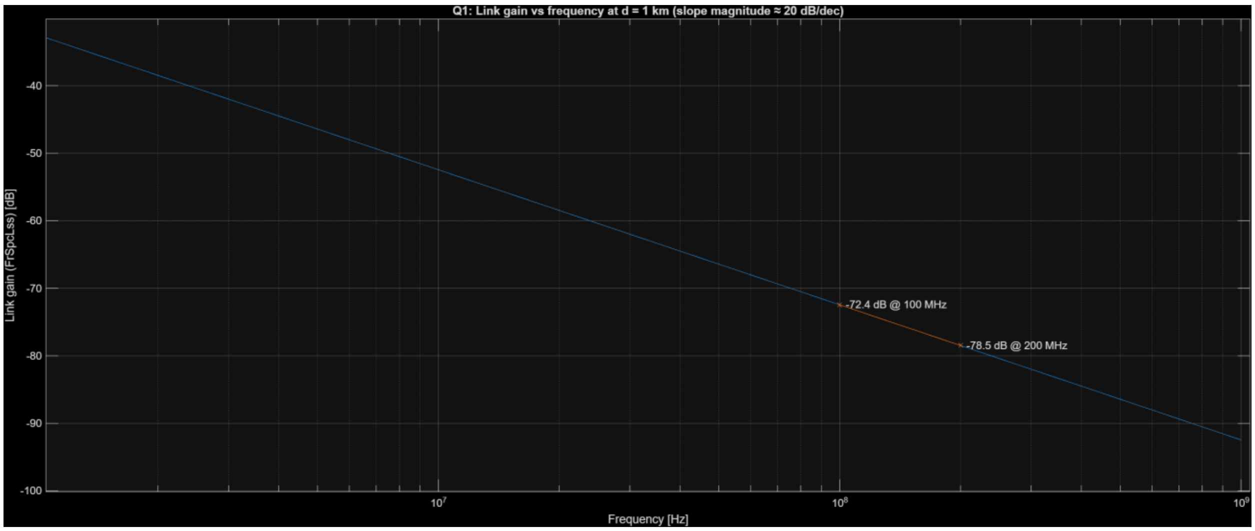
Q1. DETERMINE THE SLOPE FOR FREE SPACE PROPAGATION LOSSES VARIATION AS A FUNCTION OF FREQUENCY.

We know the FSPL expression in dB has a $20\log_{10} f$ term, so the loss grows at 20 dB/decade (≈6.02 dB per doubling). Since FrSpcLss returns link gain (which is negative and gets more negative as f increases), the change in gain per doubling is about −6.02 dB, confirming the 20 dB/decade magnitude.

The following MATLAB code plots the FrSpcLss function with constant distance and antenna gains, so it remains a function of frequency, and it allows us to visualize the slope of 20dB/decade. It also computes the difference in link gain between two frequencies, one of them being double the other.

```
function q1_slope_freq
% Q1: Slope vs frequency using FrSpcLss (returns link gain in dB).
c  = 3e8;              %#ok<NASGU> % not used directly, but kept for completeness
d  = 1000;             % 1 km
Gt = 1; Gr = 1;        % isotropic (linear gains)

f  = logspace(6,9,400);                  % 1 MHz ... 1 GHz
Lg = arrayfun(@(ff) FrSpcLss(d, ff, Gt, Gr), f);  % link gain [dB]

% Slope check (doubling frequency)
f1 = 100e6; f2 = 2*f1;
L1 = FrSpcLss(d, f1, Gt, Gr);
```

```
L2 = FrSpcLss(d, f2, Gt, Gr);
fprintf('Q1: Δ(link gain) for doubling f = %.2f dB (expected ≈ -6.02 dB)\n', L2-L1);

figure; semilogx(f, Lg); grid on;
xlabel('Frequency [Hz]'); ylabel('Link gain (FrSpcLss) [dB]');
title('Q1: Link gain vs frequency at d = 1 km (|slope| ≈ 20 dB/dec)');
hold on; plot([f1 f2],[L1 L2],'x-');
text(f1,L1,sprintf('  %.1f dB @ 100 MHz',L1));
text(f2,L2,sprintf('  %.1f dB @ 200 MHz',L2));
end
```

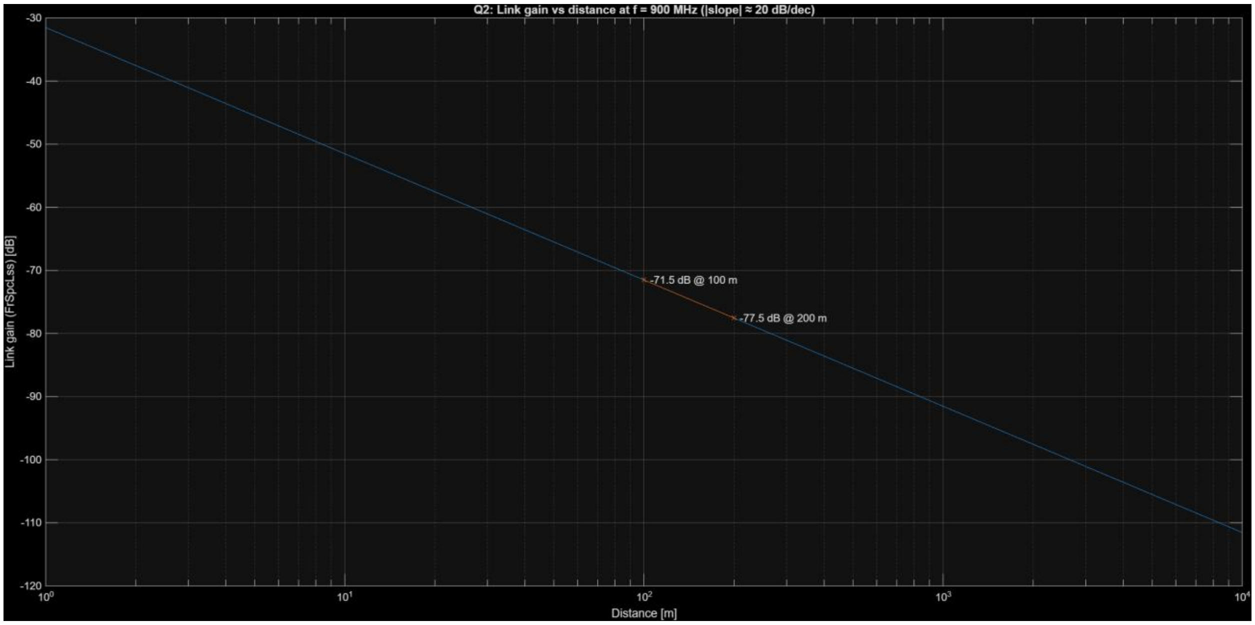


Q2. DETERMINE THE SLOPE FOR FREE SPACE PROPAGATION LOSSES VARIATION AS A FUNCTION OF DISTANCE.

FSPL also has a $20\log_{10} d$ term, so loss increases 20 dB/decade with distance (≈6.02 dB per doubling). Because FrSpcLss outputs gain, we expect the gain to drop by about 6.02 dB each time distance doubles. Here's the code that confirms it:

```
function q2_slope_dist
% Q2: Slope vs distance using FrSpcLss (returns link gain in dB).
f  = 900e6;            % 900 MHz
Gt = 1; Gr = 1;
d  = logspace(0,4,400);                % 1 m ... 10 km
Lg = arrayfun(@(dd) FrSpcLss(dd, f, Gt, Gr), d);

% Slope check (doubling distance)
d1 = 100; d2 = 2*d1;
L1 = FrSpcLss(d1, f, Gt, Gr);
L2 = FrSpcLss(d2, f, Gt, Gr);
fprintf('Q2: Δ(link gain) for doubling d = %.2f dB (expected ≈ -6.02 dB)\n', L2-L1);

figure; semilogx(d, Lg); grid on;
```

```
xlabel('Distance [m]'); ylabel('Link gain (FrSpcLss) [dB]');
title('Q2: Link gain vs distance at f = 900 MHz (|slope| ≈ 20 dB/dec)');
hold on; plot([d1 d2],[L1 L2],'x-');
text(d1,L1,sprintf('  %.1f dB @ 100 m',L1));
text(d2,L2,sprintf('  %.1f dB @ 200 m',L2));
end
```

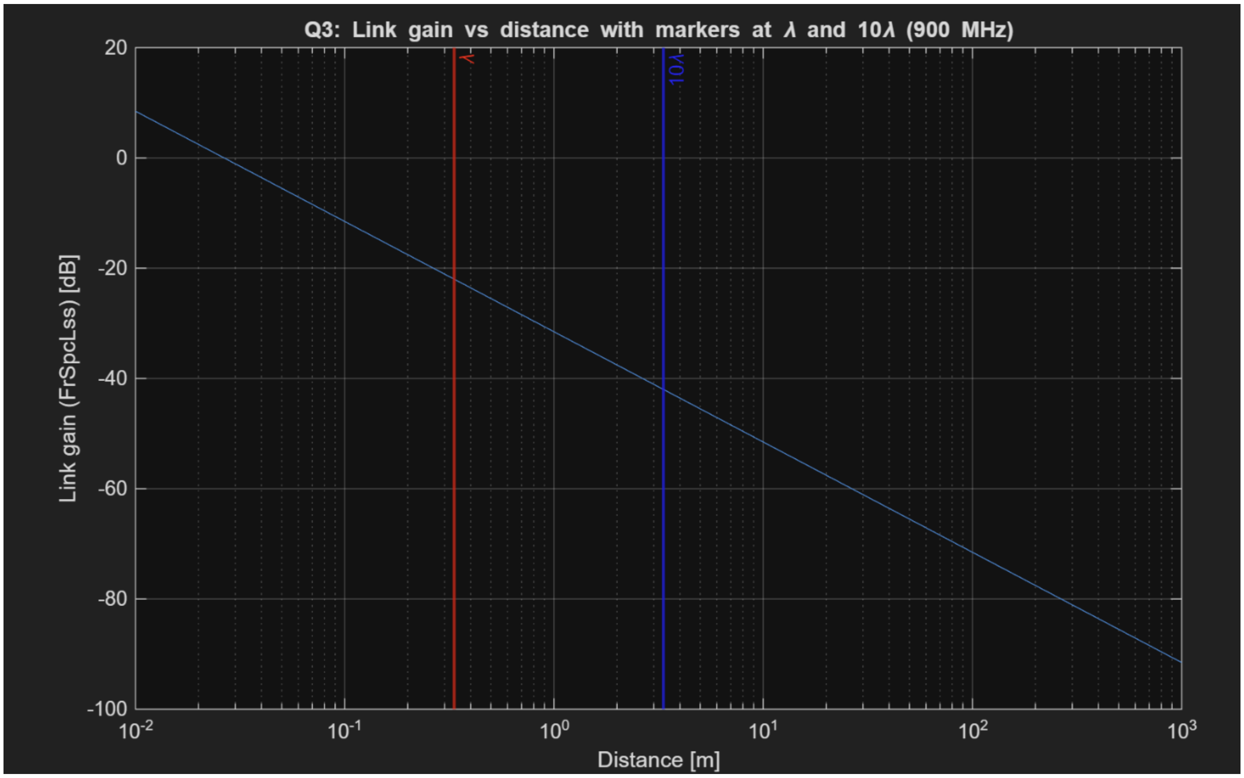


Q3. WHAT CAN BE OBSERVED IN THE PROXIMITY OF THE TRANSMITTER (DISTANCES ≈ WAVELENGTH)?

Friis/FSPL assume far-field operation, i.e., distances much larger than λ. Around a few wavelengths, near-field effects mean the simple $1/d^2$ behavior isn't reliable, near-field effects appear, reactive fields dominate, Friis equation is not accurate. We mark λ and 10λ at 900 MHz to show that boundary.

```
function q3_nearfield_demo
% Q3: Visual near-field indication with colored markers at λ and 10λ.
c  = 3e8;
f  = 900e6;
lambda = c/f;
Gt = 1; Gr = 1;

d  = logspace(-2,3,500);                % 1 cm ... 1 km
Lg = arrayfun(@(dd) FrSpcLss(dd, f, Gt, Gr), d);

fprintf('Q3: At 900 MHz, λ = %.3f m. Friis/FSPL not reliable for d ~ few·λ.\n',
lambda);
```

```
figure; semilogx(d, Lg); grid on;
xlabel('Distance [m]'); ylabel('Link gain (FrSpcLss) [dB]');
title('Q3: Link gain vs distance with markers at \lambda and 10\lambda (900 MHz)');

% Colored markers
xline(lambda,   '-', '  \lambda',  'Color', [1 0 0], 'LineWidth', 1.5);   % red
xline(10*lambda,'-', '  10\lambda','Color', [0 0 1], 'LineWidth', 1.5);   % blue
end
```



Q4. DETERMINE THE PROPAGATION LOSSES IN THE CASE WHEN THE DISTANCE BETWEEN THE TRANSMITTER AND THE RECEIVER IS D =1 KM, THE FREQUENCY OF THE SIGNAL IS F = 900 MHZ AND THE ANTENNAE HAVE A GAIN OF 2 DB. INDICATION: USE THE MATLAB FUNCTION FRSPCLSS.

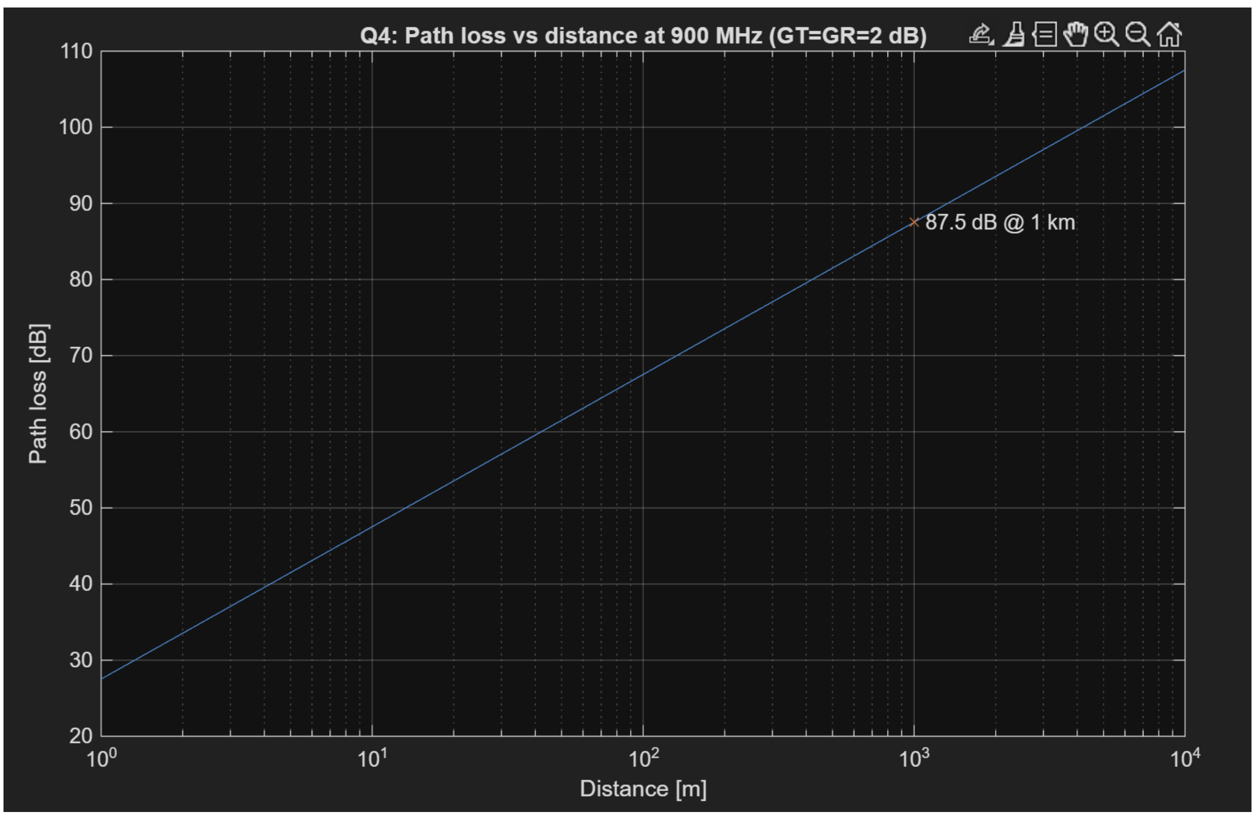
FrSpcLss gives us link gain in dB. To report loss, we take the negative of that result. We include the antenna gains by converting 2 dB to linear, calling FrSpcLss, and then computing $L_{loss} = - L_g$

```
function q4_loss_numeric
% Q4: Compute path loss at 1 km with GT=GR=2 dB, using FrSpcLss gain -> loss=-gain.
f    = 900e6;
d    = 1000;        % 1 km
GTdB = 2; GRdB = 2;
```

```
Gt    = 10^(GTdB/10);
Gr    = 10^(GRdB/10);

Lg_1km = FrSpcLss(d, f, Gt, Gr);    % link gain [dB]
L_loss = -Lg_1km;                   % path loss [dB]
fprintf('Q4: Path loss at 1 km, 900 MHz, GT=GR=2 dB: %.2f dB\n', L_loss);

% Plot loss vs distance (1 m .. 10 km) and mark 1 km
dvec = logspace(0,4,400);
Lvec = arrayfun(@(dd) -FrSpcLss(dd, f, Gt, Gr), dvec);  % compute loss inline
figure; semilogx(dvec, Lvec); grid on;
xlabel('Distance [m]'); ylabel('Path loss [dB]');
title('Q4: Path loss vs distance at 900 MHz (GT=GR=2 dB)');
hold on; plot(d, L_loss, 'x'); text(d, L_loss, sprintf('  %.1f dB @ 1 km',
L_loss));
end
```

Command Window

```
Q4: Path loss at 1 km, 900 MHz, GT=GR=2 dB: 87.53 dB
```



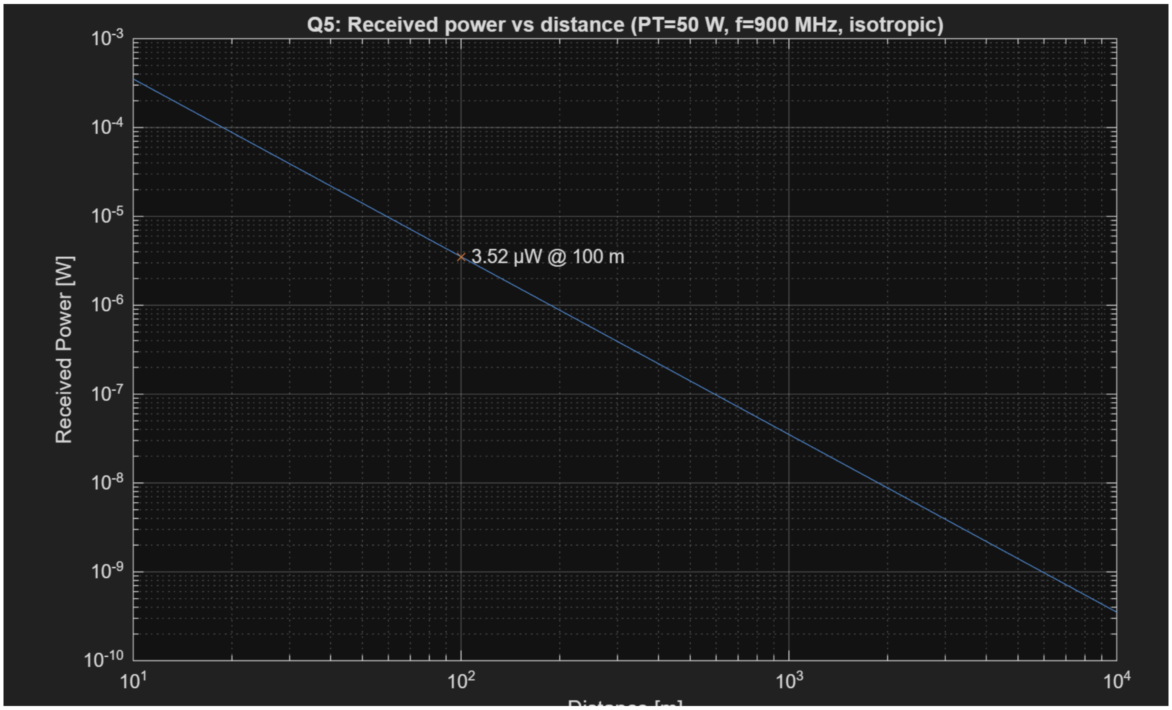
Q5. CONSIDER A RADIO TRANSMITTER WITH PT= 50 W. IF THE ANTENNA OF THE TRANSMITTER IS ISOTROPIC AND THE FREQUENCY OF THE EMITTED SIGNAL IS 900 MHZ, COMPUTE THE FREE SPACE RECEIVED POWER AT THE DISTANCE D=100M FROM THE TRANSMITTER. IT IS SUPPOSED THAT THE RECEIVER ALSO HAS AN ISOTROPIC ANTENNA.

FrSPcLss returns $10\log_{10}(P_R/P_T)$. So, we recover $P_R$via $P_R = P_T \cdot 10^{\text{FrSpcLss}(d,f,G_T,G_R)/10}$. With $P_T = 50$W, $d =$ 100m, $f = 900$MHz, isotropic gains, we expect around 3.5.

```
function q5_received_power_demo
% Q5: Received power using FrSpcLss directly.
PT   = 50;           % W
f    = 900e6;        % Hz
Gt   = 1; Gr = 1;    % isotropic
dMk = 100;           % m

LgMk   = FrSpcLss(dMk, f, Gt, Gr);      % dB of (PR/PT)
PR_Mk  = PT * 10^(LgMk/10);             % W
PR_dBm = 10*log10(PR_Mk/1e-3);
fprintf('Q5: PR @100 m, 900 MHz, PT=50 W (iso): %.3e W = %.2f µW (%.2f dBm)\n', ...
        PR_Mk, PR_Mk*1e6, PR_dBm);

% Curve PR vs distance (10 m .. 10 km)
d    = logspace(1,4,400);
Lg   = arrayfun(@(dd) FrSpcLss(dd, f, Gt, Gr), d);
PR   = PT .* 10.^(Lg/10);

figure; loglog(d, PR); grid on;
xlabel('Distance [m]'); ylabel('Received Power [W]');
title('Q5: Received power vs distance (PT=50 W, f=900 MHz, isotropic)');
hold on; plot(dMk, PR_Mk, 'x');
text(dMk, PR_Mk, sprintf('  %.2f µW @ 100 m', PR_Mk*1e6));
end
```

Command Window

```
Q5: PR @100 m, 900 MHz, PT=50 W (iso): 3.518e-06 W = 3.52 µW (-24.54 dBm)
```



Q6. IF THE POWER RECEIVED BY AN ANTENNA HAVING THE GAIN IS , AND THE FREQUENCY OF THE SIGNAL IS F=900MHZ, DETERMINE THE INTENSITY OF THE ELECTRICAL FIELD AT THE RECEIVER. INDICATION: RELATION (3) SHOULD BE USED.

We used the lab relations $A_e = \frac{G_R\lambda^2}{4\pi}$, $S = \frac{P_R}{A_e}$, and $S = \frac{E^2}{\eta} \Rightarrow E = \sqrt{S\eta}$ with $\eta \approx 377$. Plugging P_R, G_R, and f gives E in V/m.

```
function q6_field_from_power_demo
% Q6: Compute |E| from PR, GR, f (direct formulas; no helpers).
c   = 3e8;          % [m/s]
eta = 377;          % [ohm]
PR  = 7e-10;        % [W]
GR  = 2;            % linear power gain
f   = 900e6;        % [Hz]

lambda = c / f;
Ae = GR * lambda^2 / (4*pi);   % effective aperture [m^2]
S  = PR / Ae;                   % power flux density [W/m^2]
E  = sqrt(S * eta);             % field magnitude [V/m]

fprintf('Q6: E ≈ %.4f V/m = %.2f mV/m (at 900 MHz, GR=2, PR=7e-10 W)\n', E, E*1e3);

% Visual: E vs PR with the given point
PR_range = logspace(-12,-6,400);
Ae_const = Ae;                  % constant for fixed GR and f
E_curve  = sqrt((PR_range./Ae_const) * eta);
```

```
figure; semilogx(PR_range, E_curve); grid on;
xlabel('Received Power PR [W]'); ylabel('E-field magnitude [V/m]');
title('Q6: E-field vs PR (GR=2, f=900 MHz)');
hold on; plot(PR, E, 'x'); text(PR, E, sprintf('  %.2f mV/m @ %.1e W', E*1e3, PR));
end
```

Command Window

```
Q6: E ≈ 0.0039 V/m = 3.86 mV/m (at 900 MHz, GR=2, PR=7e-10 W)
```