```
clc; clearvars;

f = 433e6; % frequency in Hertz
Re = 6371e3; % Earth radius in metres
h  = 450e3; % satellite altitude above Earth's surface in metres
elevation_angles = 5:5:90; % elevation angle range in degrees

P_t = -10; % includes HPA, Power of the transmitter in dBw
G_t = 0; % gain of the antenna, in dBi
L_txsystem = 1; %losses due to feeding lines, connectors, filters, HPA etc in dB
L_fspl = 0; %free space path loss (calculation below) in dB
L_atm = 1; %atmospheric, rain, clouds, fog, ionosphere attenuation + (Diffusion-
due to obstacles- neglect) + (Multipath fading- only for terrestrial- neglect) in dB
L_plrz = 3; %polarization mismatch, effectively 0 for circularly polarised antennas
in dB
L_point = 1; % pointing losses, add both reciever and transmitter pointing losses
in dB

G_r = 8; % gain of ground station in dBi
G_lna_ext = 15; %gain of external lna, see below for effect on F in dBi
L_rxsystem = 1; %losses due to feeding lines, connectors, filters, LNA,
demodulators etc in dB

S_datasheet = -136; %sensitivity on datasheet (already includes the internal LNA
gain effect an noise spectrum density change) in dBm
T_cold = 200; %At zenith
T_hot  = 1000; %at horizon
T_ant = 0; %Thermal temperature, Tsky(atmospheric thermal temp) + Tgnd(due to sie
and back lobes) in K, Calculation below
B_datasheet = 125e3; %Bandwidth of reciever in Hz
SNRrequired_datasheet = -20; %required signal to noise ratio for the reciever to be
able to demod the signal in dB

U_bitrate = 293e-6; %bitrate that WE pass, megabits per second
EbNo_threshold = 7.1; %minimum Eb/No required by the reciever, in dB

% Preallocate arrays
LINKMARGINP_via_sensitivity = zeros(size(elevation_angles));
LINKMARGINP_via_ebno = zeros(size(elevation_angles));
r_all = zeros(size(elevation_angles));
L_fspl_all = zeros(size(elevation_angles));
Ts_actual_all = zeros(size(elevation_angles));
CNo_all = zeros(size(elevation_angles));
EbNo_all = zeros(size(elevation_angles));

for i = 1:length(elevation_angles)
    el = elevation_angles(i); % current elevation angle
    fprintf('\n=== Elevation Angle: %.1f° ===\n', el);
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    r = sqrt((Re + h)^2 - (Re * cosd(el))^2) - Re * sind(el); % Compute slant range
(distance from ground station to satellite)
    EIRP = P_t + G_t - L_txsystem; %effective output power in dBm
    L_fspl = 20*log10(4*pi*r*f/299792458);
    L_prop = L_fspl + L_atm; %propogation losses

    Pr = EIRP - L_prop - L_plrz - L_point + G_r + G_lna_ext - L_rxsystem;
    C = Pr; %recieved power to digital system at reciever end, in dBm
    T_ant = T_cold + (T_hot - T_cold) * (1 - sind(el)); %using Thot an Tcold to
model elevation differences
    N = S_datasheet - SNRrequired_datasheet; %noise power
    NF = N + 174 - 10*log10(B_datasheet); %noise figure at datasheet
    F = 10^(NF/10); %noise factor at datasheet

    % if external lna connected - F = Flna + (Frx - 1)/G_lna_ext;

    Tr = (F-1)*290; %Thermal temp at reciever end
    Ts_actual = T_ant + Tr; %Thermal temp of system incluing Tatm and Tr (entire
system)
    Ts_spec = F*290; %Thermal temp use by mnufacturer to calculate
    correction = 10*log10(Ts_actual/Ts_spec); %change due to Tatm

    S_actual = S_datasheet + correction; %actual sensitivity of reciever system
    Psensitivity = S_actual;
    LINKMARGINP_via_sensitivity(i) = Pr - Psensitivity;

    No = 1.380649e-23 * Ts_actual; %Noise spectral density in W/Hz
    No = 10*log10(No); %nsd in dBW/Hz

    C_ = C - 30; %C in dBW
    CNo = C_ - No; %received carrier power/noise spectral density in dB-Hz
    EbNo_calculated = CNo - 10*log10(U_bitrate) - 60; %received EbNo in dB, 60
subtracte to convert from Mbps to bps
    LINKMARGINP_via_ebno(i) = EbNo_calculated - EbNo_threshold;

    % Store results for table
    r_all(i) = r;
    L_fspl_all(i) = L_fspl;
    Ts_actual_all(i) = Ts_actual;
    CNo_all(i) = CNo;
    EbNo_all(i) = EbNo_calculated;

    % Print key values for this elevation
    fprintf('Slant range (r): %.2f km\n', r/1e3);
    fprintf('Free-space path loss (L_fspl): %.2f dB\n', L_fspl);
    fprintf('System temperature (Ts_actual): %.2f K\n', Ts_actual);
    fprintf('C/N0: %.2f dB-Hz\n', CNo);
    fprintf('Eb/No: %.2f dB\n', EbNo_calculated);
    fprintf('Link Margin (via Eb/No): %.2f dB\n', LINKMARGINP_via_ebno(i));
    fprintf('----------------------------------------\n');
```

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end
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```
=== Elevation Angle: 5.0° ===
Slant range (r): 1943.68 km
Free-space path loss (L_fspl): 150.95 dB
System temperature (Ts_actual): 2104.10 K
C/N0: 20.42 dB-Hz
Eb/No: -4.25 dB
Link Margin (via Eb/No): -11.35 dB
----------------------------------------
=== Elevation Angle: 10.0° ===
Slant range (r): 1569.57 km
Free-space path loss (L_fspl): 149.09 dB
System temperature (Ts_actual): 2034.90 K
C/N0: 22.42 dB-Hz
Eb/No: -2.25 dB
Link Margin (via Eb/No): -9.35 dB
----------------------------------------
=== Elevation Angle: 15.0° ===
Slant range (r): 1293.07 km
Free-space path loss (L_fspl): 147.41 dB
System temperature (Ts_actual): 1966.77 K
C/N0: 24.25 dB-Hz
Eb/No: -0.42 dB
Link Margin (via Eb/No): -7.52 dB
----------------------------------------
=== Elevation Angle: 20.0° ===
Slant range (r): 1089.70 km
Free-space path loss (L_fspl): 145.92 dB
System temperature (Ts_actual): 1900.20 K
C/N0: 25.89 dB-Hz
Eb/No: 1.22 dB
Link Margin (via Eb/No): -5.88 dB
----------------------------------------
=== Elevation Angle: 25.0° ===
Slant range (r): 938.75 km
Free-space path loss (L_fspl): 144.63 dB
System temperature (Ts_actual): 1835.73 K
C/N0: 27.33 dB-Hz
Eb/No: 2.66 dB
Link Margin (via Eb/No): -4.44 dB
----------------------------------------
=== Elevation Angle: 30.0° ===
Slant range (r): 824.96 km
Free-space path loss (L_fspl): 143.51 dB
System temperature (Ts_actual): 1773.82 K
C/N0: 28.60 dB-Hz
Eb/No: 3.94 dB
Link Margin (via Eb/No): -3.16 dB
----------------------------------------
=== Elevation Angle: 35.0° ===
Slant range (r): 737.78 km
Free-space path loss (L_fspl): 142.54 dB
System temperature (Ts_actual): 1714.96 K
C/N0: 29.72 dB-Hz
Eb/No: 5.05 dB
Link Margin (via Eb/No): -2.05 dB
----------------------------------------
=== Elevation Angle: 40.0° ===
Slant range (r): 669.99 km
Free-space path loss (L_fspl): 141.70 dB
System temperature (Ts_actual): 1659.59 K
C/N0: 30.70 dB-Hz
Eb/No: 6.03 dB
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Link Margin (via Eb/No): -1.07 dB
----------------------------------------
=== Elevation Angle: 45.0° ===
Slant range (r): 616.67 km
Free-space path loss (L_fspl): 140.98 dB
System temperature (Ts_actual): 1608.14 K
C/N0: 31.56 dB-Hz
Eb/No: 6.89 dB
Link Margin (via Eb/No): -0.21 dB
----------------------------------------
=== Elevation Angle: 50.0° ===
Slant range (r): 574.38 km
Free-space path loss (L_fspl): 140.36 dB
System temperature (Ts_actual): 1560.99 K
C/N0: 32.30 dB-Hz
Eb/No: 7.63 dB
Link Margin (via Eb/No): 0.53 dB
----------------------------------------
=== Elevation Angle: 55.0° ===
Slant range (r): 540.74 km
Free-space path loss (L_fspl): 139.84 dB
System temperature (Ts_actual): 1518.50 K
C/N0: 32.95 dB-Hz
Eb/No: 8.28 dB
Link Margin (via Eb/No): 1.18 dB
----------------------------------------
=== Elevation Angle: 60.0° ===
Slant range (r): 514.02 km
Free-space path loss (L_fspl): 139.40 dB
System temperature (Ts_actual): 1481.00 K
C/N0: 33.50 dB-Hz
Eb/No: 8.83 dB
Link Margin (via Eb/No): 1.73 dB
----------------------------------------
=== Elevation Angle: 65.0° ===
Slant range (r): 493.01 km
Free-space path loss (L_fspl): 139.03 dB
System temperature (Ts_actual): 1448.77 K
C/N0: 33.95 dB-Hz
Eb/No: 9.29 dB
Link Margin (via Eb/No): 2.19 dB
----------------------------------------
=== Elevation Angle: 70.0° ===
Slant range (r): 476.81 km
Free-space path loss (L_fspl): 138.74 dB
System temperature (Ts_actual): 1422.07 K
C/N0: 34.33 dB-Hz
Eb/No: 9.66 dB
Link Margin (via Eb/No): 2.56 dB
----------------------------------------
=== Elevation Angle: 75.0° ===
Slant range (r): 464.78 km
Free-space path loss (L_fspl): 138.52 dB
System temperature (Ts_actual): 1401.08 K
C/N0: 34.61 dB-Hz
Eb/No: 9.94 dB
Link Margin (via Eb/No): 2.84 dB
----------------------------------------
=== Elevation Angle: 80.0° ===
Slant range (r): 456.47 km
Free-space path loss (L_fspl): 138.37 dB
System temperature (Ts_actual): 1385.97 K
C/N0: 34.82 dB-Hz
Eb/No: 10.15 dB
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Link Margin (via Eb/No): 3.05 dB
----------------------------------------
=== Elevation Angle: 85.0° ===
Slant range (r): 451.60 km
Free-space path loss (L_fspl): 138.27 dB
System temperature (Ts_actual): 1376.87 K
C/N0: 34.94 dB-Hz
Eb/No: 10.27 dB
Link Margin (via Eb/No): 3.17 dB
----------------------------------------
=== Elevation Angle: 90.0° ===
Slant range (r): 450.00 km
Free-space path loss (L_fspl): 138.24 dB
System temperature (Ts_actual): 1373.82 K
C/N0: 34.98 dB-Hz
Eb/No: 10.31 dB
Link Margin (via Eb/No): 3.21 dB
----------------------------------------
```

```
% Produce table of results
Results = table(elevation_angles.', r_all.'/1e3, L_fspl_all.', Ts_actual_all.', ...
    CNo_all.', EbNo_all.', LINKMARGINP_via_sensitivity.', LINKMARGINP_via_ebno.',
...
    'VariableNames', {'Elevation_deg', 'SlantRange_km', 'L_fspl_dB', 'Ts_K', ...
    'CNo_dBHz', 'EbNo_dB', 'LinkMargin_Sens_dB', 'LinkMargin_EbNo_dB'});

disp(Results);
```

Elevation_deg	SlantRange_km	L_fspl_dB	Ts_K	CNo_dBHz	EbNo_dB	LinkMargin_Sens_dB	LinkMargi
5	1943.7	150.95	2104.1	20.418	-4.2502	-10.526	-1
10	1569.6	149.09	2034.9	22.421	-2.2481	-8.5237	-9
15	1293.1	147.41	1966.8	24.252	-0.41701	-6.6926	-7
20	1089.7	145.92	1900.2	25.887	1.2188	-5.0568	-5
25	938.75	144.63	1835.7	27.333	2.6639	-3.6117	-4
30	824.96	143.51	1773.8	28.604	3.9352	-2.3404	-3
35	737.78	142.54	1715	29.721	5.0519	-1.2237	-2
40	669.99	141.7	1659.6	30.7	6.0315	-0.24408	-1
45	616.67	140.98	1608.1	31.557	6.8887	0.61313	-0.2
50	574.38	140.36	1561	32.304	7.635	1.3594	0.5
55	540.74	139.84	1518.5	32.948	8.2791	2.0035	1
60	514.02	139.4	1481	33.496	8.8278	2.5521	1
65	493.01	139.03	1448.8	33.955	9.2859	3.0102	2
70	476.81	138.74	1422.1	34.326	9.6569	3.3813	2
75	464.78	138.52	1401.1	34.612	9.9434	3.6678	2
80	456.47	138.37	1386	34.816	10.147	3.8715	3
85	451.6	138.27	1376.9	34.938	10.269	3.9933	3
90	450	138.24	1373.8	34.978	10.309	4.0338	3

```
% Plot link margins vs elevation angle
figure;
plot(elevation_angles, LINKMARGINP_via_sensitivity, '-o', 'LineWidth', 1.5); hold
on;
plot(elevation_angles, LINKMARGINP_via_ebno, '-s', 'LineWidth', 1.5);
grid on;
xlabel('Elevation Angle (°)');
```

```
ylabel('Link Margin (dB)');
title('Link Margin vs Elevation Angle');
legend('Via Sensitivity', 'Via Eb/No', 'Location', 'best');
```