

LTE Link Budget Model

Problem: Produce a model to calculate the range and coverage area for an LTE FDD eNodeB with 3 sectors in a rural environment, as a function of the minimum service (data rate) required, uplink and downlink, specified at the cell edge. The rates need not be the same (e.g. 1Mbps downlink and 200kbps uplink). Assume cell site uses 4 Tx/Rx antennas, UE has just one Tx antenna, 2 Rx.

Method: As it is for rural areas, we shall assume a frequency band 20 (800MHz, see table from 3GPP TS 36.101 below).

Use the Hata- based propagation model depending on distance r , frequency f , cell antenna height h and user antenna height u . For this band we have a small city model adapted to urban environment,

Path Loss $L = 69.55 + 26.16 \cdot \log f - 13.82 \cdot \log h + (44.9 - 6.55 \log h) \log r + UHG(u)$

Where User antenna height gain $UHG(u) = u(1.1 \log f - 0.7) - 1.56 \log f + 0.8$

and the Adjusted path Loss $APL = PLX - HRA - LNS - BPL - BDL$ (definitions below)

We define the cell edge as being where the Signal to Noise Ratio and the Available bandwidth per user provide the data rate equal to the cell edge data rate (CEDR) specified.

We use an excel spreadsheet to calculate the values of peak cell range r meeting these conditions.

Allow for the LTE Bandwidths of 5- 20 MHz

Note: in general one direction will have a smaller range than the other. need to find the limiting link r_1 : uplink or downlink?

Use Coverage Area $CA = 2 r_1^2$ (Optional exercise: show this is a good approximation for clover leaf)

To test the model, try varying:

- cell antenna height,
- user antenna height,
- building penetration loss,
- cell edge data rate,
- frequency band -try bands 3, 7

Parameters

ABU: Available Bandwidth/User; $ABU_{DL}=3.4\text{MHz}$, $ABU_{UL}=0.09\text{LBW}$

AC:Antenna Configuration $AC=6\text{dB(DL)}$, 0dB (UL) (based on 4TX nw antennas, 1 at UE)

AG: Antenna gain; $AG(eNB)=17\text{dBi}$; $AG(UE)=-3\text{dBi}$;

APL: Adjusted Path Loss; $APL=PLX-HRA-LNS-BPL-BDL$

ATxP: Antenna Transmit Power; $ATxP(DL)=43\text{dBm}$; $ATxP(UL)=23\text{dBm}$

AHF: Antenna Height Factor; $AHF=(70+26*\log f-14*\log h)/(45-6.6*\log h)$

AHFD: Antenna Height factor denominator; $AHFD=45-6.6\log h$

BDL: Body Loss; $BDL=2\text{dB}$

BPL : Building Penetration Loss ; $BPL=10 \text{ à } 20$ (typical : 14dB)

CEDR: Cell Edge Data Rate (Mbps);

EBF: Effective Bandwidth factor; $EBF=0.5$

$EIRP=ATxP+OTP+AC-FL+AG$

$f=\text{frequency (MHz)}$

FL: Feeder loss; $FL(DL)=2\text{dB}$; $FL(UL)=0\text{dB}$

$h=\text{cell antenna height (m)}$

HRA: Hata Rural Adjustment; $HRA=-4.8(\log f)^2 + 18\log f - 41$

HPN: Hata Path Numerator= $APL-69.55-26.16*\log f+13.82*\log h+UHG$

IFM: interference margin; $IFM(DL)=3\text{ dB}$; $IFM(UL)=1\text{ dB}$

LBW: LTE Bandwidth: 5, 10, 15, 20 MHz

LNS : Log-Normal Shadowing Allowance; $LNS=4.35\text{dB}$

$n=\text{number of receive antennas}$. Example: $n(UE)=2$; $n(eNB)=4$

OTP: Overhead Transmit Power; -1dB bothway

$PLX=\text{Max Path Loss}$; $PLX=EIRP-IFM-RxS+AG+DIG$

$r:\text{cell range}=10\exp(HPN/AHFD)(\text{km})$

RDG: Receive Diversity Gain; $RDG=10\log n$

RNF: Receiver Noise Figure; $RNF(DL)=7\text{dB}$, $RNF(UL)=2\text{dB}$

$RxS:\text{Receive sensitivity}$; $RxS=RNF+THN+SNRT$

SER Spectral efficiency required; $SER=CEDR/ABU$

SNRL SNR Shannon Implementation Loss 2dB

SNRT: Signal to noise ratio target: $SNRT=10\log(2^{(SER)}-1)+SIM$

THN: Thermal Noise; $THN=10\log BN-113\text{ dB}$

$u=\text{user antenna height (m)}$

UHG: User antenna height gain $UHG=0.8+(1.1\log f-0.7)*u-1.56\log f$

UPC Users per cell

Table 5.5-1 E-UTRA operating bands

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	F_{UL_low} – F_{UL_high}	F_{DL_low} – F_{DL_high}	
1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
4	1710 MHz – 1755 MHz	2110 MHz – 2155 MHz	FDD
5	824 MHz – 849 MHz	869 MHz – 894MHz	FDD
6 ¹	830 MHz – 840 MHz	875 MHz – 885 MHz	FDD
7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
9	1749.9 MHz – 1784.9 MHz	1844.9 MHz – 1879.9 MHz	FDD
10	1710 MHz – 1770 MHz	2110 MHz – 2170 MHz	FDD
11	1427.9 MHz – 1447.9 MHz	1475.9 MHz – 1495.9 MHz	FDD
12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
15	Reserved	Reserved	FDD
16	Reserved	Reserved	FDD
17	704 MHz – 716 MHz	734 MHz – 746 MHz	FDD
18	815 MHz – 830 MHz	860 MHz – 875 MHz	FDD
19	830 MHz – 845 MHz	875 MHz – 890 MHz	FDD
20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
21	1447.9 MHz – 1462.9 MHz	1495.9 MHz – 1510.9 MHz	FDD
22	3410 MHz – 3490 MHz	3510 MHz – 3590 MHz	FDD
23	2000 MHz – 2020 MHz	2180 MHz – 2200 MHz	FDD
24	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD
25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
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33	1900 MHz – 1920 MHz	1900 MHz – 1920 MHz	TDD
34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
35	1850 MHz – 1910 MHz	1850 MHz – 1910 MHz	TDD
36	1930 MHz – 1990 MHz	1930 MHz – 1990 MHz	TDD
37	1910 MHz – 1930 MHz	1910 MHz – 1930 MHz	TDD
38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
42	3400 MHz – 3600 MHz	3400 MHz – 3600 MHz	TDD
43	3600 MHz – 3800 MHz	3600 MHz – 3800 MHz	TDD
Note 1: Band 6 is not applicable			