Modelo de propagación en espacio libre (ec. de Friis)

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L}$$

$$PL[\text{dB}] = 10\log\left(\frac{P_t}{P_r}\right) = -10\log\left(\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2 L}\right)$$

$= 10\log\left[\left(\frac{4\cdot\pi\cdot d}{\lambda}\right)^2\right]$ = dB = $\left(\frac{4\cdot\pi\cdot d}{\lambda}\right)^2$ veces

Espacio libre simplificado (exponente de pérdidas igual a 2)

$$P_r(d)[\text{dBm}] = 10\log\left(\frac{P_r^{Friis}(d_0)[\text{mW}]}{0.001\text{W}}\right) + 20\log\left(\frac{d_0}{d}\right)$$

$P_r[dBm] = Pt + Gt + Gr - PL - L$

PIRE = Pt · Gt veces

Path Loss simplificado con exponente de pérdidas general

$$P_r[\text{dBm}] = 10\log\left(\frac{P_r^{Friis}(d_0)[\text{mW}]}{0.001\text{W}}\right) - 10\gamma\log_{10}\left(\frac{d}{d_0}\right)$$

$P_R[dBm] = Pt + Gt + Gr + 10 \cdot \log_{10}\left(\frac{4\cdot\pi\cdot d}{\lambda}\right)$

$\lambda = c/f$ PL

Modelo de dos rayos

$$P_r[\text{dBm}] = P_t[\text{dBm}] + 10\log_{10}(G_t G_r) + 20\log_{10}(h_t h_r) - 40\log_{10}(d)$$

Pérdidas por un obstáculo "filo de cuchillo"

Obs: pérdidas referenciadas a las pérdidas del haz directo en espacio libre.

$$v = h\sqrt{\frac{2(d+d')}{\lambda d d'}}$$

$$L(v)(dB) = \begin{cases} 20\log_{10}[0.5 - 0.62v] & -0.8 \le v < 0 \\ 20\log_{10}[0.5e^{-.95v}] & 0 \le v < 1 \\ 20\log_{10}[0.4 - \sqrt{.1184 - (.38 - .1v)^2}] & 1 \le v < 2.4 \\ 20\log_{10}[.225/v] & v > 2.4 \end{cases}$$

Modelo de Okumura

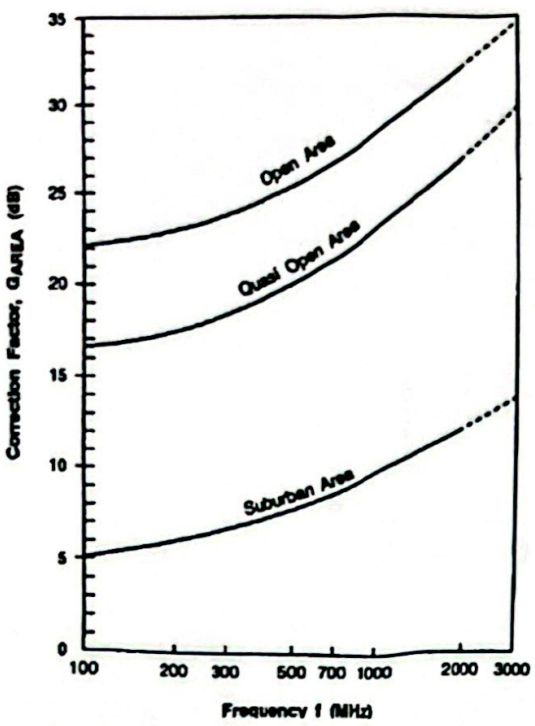
$$P_R[\text{dBm}] = EIRP[\text{dBm}] - L_{50}[\text{dB}] + G_R[\text{dB}]$$

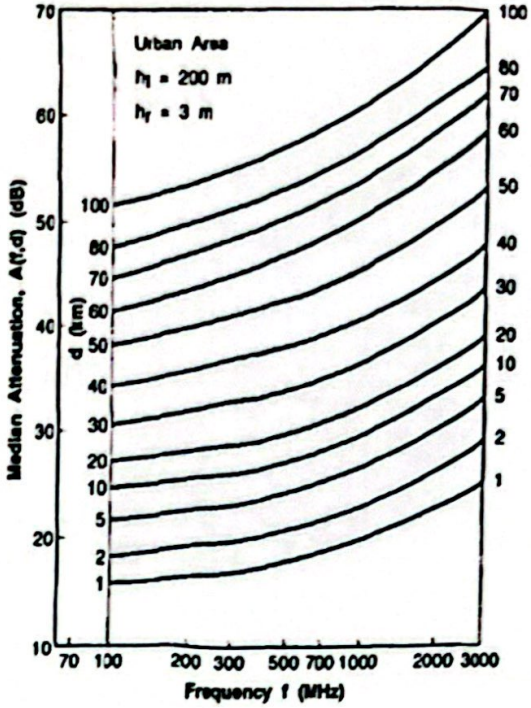
$$L_{50}[dB] = L_f + A_{mu}(f,d) - G(h_t) - G(h_r) - G_{AREA}$$

$10\log\left(\left(\frac{4\pi d}{\lambda}\right)^2\right) = dB$

$$G(h_t) = 20\log_{10}(h_t/200), \quad 30m < h_t < 1000m$$

$$G(h_r) = \begin{cases} 10\log_{10}(h_r/3) & h_r \le 3m \\ 20\log_{10}(h_r/3) & 3m < h_r < 10m \end{cases}$$





Modelo de Hata

Zonas urbanas:

$$L_{50}(urban)(\text{dB}) = 69.55 + 26.16\log f_c - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55\log h_{te})\log d$$

Ciudades pequeñas y medianas:

$$a(h_{re}) = (1.1\log f_c - 0.7)h_{re} - (1.56\log f_c - 0.8)\,\text{dB}$$

Grandes ciudades

$$a(h_{re}) = 8.29(\log 1.54h_{re})^2 - 1.1\ \text{dB} \quad \text{for } f_c \le 300\ \text{MHz}$$

$$a(h_{re}) = 3.2(\log 11.75h_{re})^2 - 4.97\ \text{dB} \quad \text{for } f_c \ge 300\ \text{MHz}$$

Zonas suburbanas

$$L_{50}(\text{dB}) = L_{50}(urban) - 2[\log(f_c/28)]^2 - 5.4$$

Zonas rurales

$$L_{50}(\text{dB}) = L_{50}(urban) - 4.78(\log f_c)^2 - 18.33\log f_c - 40.98$$

f_c en MHz, alturas en metros, d en Km.

Modelo COST 231

$$L_{50}(urban) = 46.3 + 33.9\log f_c - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55\log h_{te})\log d + C_M$$

$$C_M = \begin{cases} 0\ \text{dB} & \text{Ciudades pequeñas y suburbanas} \\ 3\ \text{dB} & \text{Centros metropolitanos} \end{cases}$$

$$Q = \frac{D}{R} = \sqrt{3N}$$

;

$$\frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}}$$

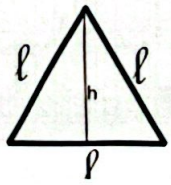
;

$$\frac{S}{I} = \frac{(D/R)^n}{i_0} = \frac{\left(\sqrt{3N}\right)^n}{i_0}$$

;

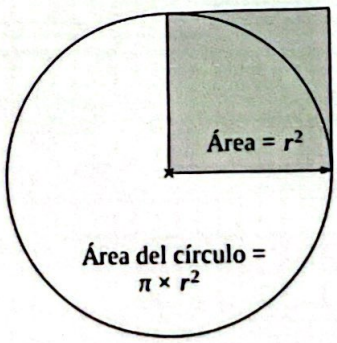
$$\frac{S}{I} = \frac{1}{2(Q-1)^{-4} + 2(Q+1)^{-4} + 2Q^{-4}}$$

Triângulo Equilátero



S = ÁREA

$$S = \frac{\ell^2 \sqrt{3}}{4}$$



N/B	0.01	0.05	0.1	0.5	1	2	5	10	15	20	30	40
1	0.0001	0.0005	0.0010	0.0050	0.0101	0.0204	0.1	0.1	0.2	0.3	0.4	0.7
2	0.0142	0.0321	0.0458	0.1	0.2	0.2	0.4	0.6	0.8	1.0	1.4	2.0
3	0.1	0.2	0.2	0.3	0.5	0.6	0.9	1.3	1.6	1.9	2.6	3.5
4	0.2	0.4	0.4	0.7	0.9	1.1	1.5	2.0	2.5	2.9	3.9	5.0
5	0.5	0.6	0.8	1.1	1.4	1.7	2.2	2.9	3.5	4.0	5.2	6.6
6	0.7	1.0	1.1	1.6	1.9	2.3	3.0	3.8	4.4	5.1	6.5	8.2
7	1.1	1.4	1.6	2.2	2.5	2.9	3.7	4.7	5.5	6.2	7.9	9.8
8	1.4	1.8	2.1	2.7	3.1	3.6	4.5	5.6	6.5	7.4	9.2	11.4
9	1.8	2.3	2.6	3.3	3.8	4.3	5.4	6.5	7.6	8.5	10.6	13.1
10	2.3	2.8	3.1	4.0	4.5	5.1	6.2	7.5	8.6	9.7	12.0	14.7
11	2.7	3.3	3.7	4.6	5.2	5.8	7.1	8.5	9.7	10.9	13.3	16.3
12	3.2	3.9	4.2	5.3	5.9	6.6	8.0	9.5	10.8	12.0	14.7	18.0
13	3.7	4.4	4.8	6.0	6.6	7.4	8.8	10.5	11.9	13.2	16.1	19.6
14	4.2	5.0	5.4	6.7	7.4	8.2	9.7	11.5	13.0	14.4	17.5	21.2
15	4.8	5.6	6.1	7.4	8.1	9.0	10.6	12.5	14.1	15.6	18.9	22.9
16	5.3	6.3	6.7	8.1	8.9	9.8	11.5	13.5	15.2	16.8	20.3	24.5
17	5.9	6.9	7.4	8.8	9.7	10.7	12.5	14.5	16.3	18.0	21.7	26.2
18	6.5	7.5	8.0	9.6	10.4	11.5	13.4	15.6	17.4	19.2	23.1	27.8
19	7.1	8.2	8.7	10.3	11.2	12.3	14.3	16.6	18.5	20.4	24.5	29.5
20	7.7	8.8	9.4	11.1	12.0	13.2	15.3	17.6	19.7	21.6	25.9	31.2
21	8.3	9.5	10.1	11.9	12.8	14.0	16.2	18.7	20.8	22.9	27.3	32.8
22	8.9	10.2	10.8	12.6	13.7	14.9	17.1	19.7	21.9	24.1	28.7	34.5
23	9.6	10.9	11.5	13.4	14.5	15.8	18.1	20.7	23.0	25.3	30.2	36.1
24	10.2	11.6	12.2	14.2	15.3	16.6	19.0	21.8	24.2	26.5	31.6	37.8
25	10.9	12.3	13.0	15.0	16.1	17.5	20.0	22.8	25.3	27.7	33.0	39.4
26	11.5	13.0	13.7	15.8	17.0	18.4	20.9	23.9	26.4	28.9	34.4	41.1
27	12.2	13.7	14.4	16.6	17.8	19.3	21.9	24.9	27.6	30.2	35.8	42.8
28	12.9	14.4	15.2	17.4	18.6	20.2	22.9	26.0	28.7	31.4	37.2	44.4
29	13.6	15.1	15.9	18.2	19.5	21.0	23.8	27.1	29.9	32.6	38.6	46.1
30	14.3	15.9	16.7	19.0	20.3	21.9	24.8	28.1	31.0	33.8	40.1	47.7
31	14.9	16.6	17.4	19.9	21.2	22.8	25.8	29.2	32.1	35.1	41.5	49.4
32	15.6	17.3	18.2	20.7	22.1	23.7	26.8	30.2	33.3	36.3	42.9	51.1
33	16.3	18.1	19.0	21.5	22.9	24.6	27.7	31.3	34.4	37.5	44.3	52.7
34	17.0	18.8	19.7	22.3	23.8	25.5	28.7	32.4	35.6	38.8	45.7	54.4
35	17.8	19.6	20.5	23.2	24.6	26.4	29.7	33.4	36.7	40.0	47.1	56.0
36	18.5	20.4	21.3	24.0	25.5	27.3	30.7	34.5	37.9	41.2	48.6	57.7
37	19.2	21.1	22.1	24.9	26.4	28.3	31.6	35.6	39.0	42.5	50.0	59.4
38	19.9	21.9	22.9	25.7	27.3	29.2	32.6	36.6	40.2	43.7	51.4	61.0
39	20.6	22.6	23.7	26.5	28.1	30.1	33.6	37.7	41.3	44.9	52.8	62.7
40	21.4	23.4	24.4	27.4	29.0	31.0	34.6	38.8	42.5	46.2	54.2	64.4
41	22.1	24.2	25.2	28.2	29.9	31.9	35.6	39.9	43.6	47.4	55.7	66.0
42	22.9	25.0	26.0	29.1	30.8	32.8	36.6	40.9	44.8	48.6	57.1	67.7
43	23.6	25.8	26.8	29.9	31.7	33.8	37.6	42.0	45.9	49.9	58.5	69.3
44	24.3	26.5	27.6	30.8	32.5	34.7	38.6	43.1	47.1	51.1	59.9	71.0
45	25.1	27.3	28.5	31.7	33.4	35.6	39.6	44.2	48.3	52.3	61.4	72.7
46	25.8	28.1	29.3	32.5	34.3	36.5	40.6	45.2	49.4	53.6	62.8	74.3
47	26.6	28.9	30.1	33.4	35.2	37.5	41.5	46.3	50.6	54.8	64.2	76.0
48	27.3	29.7	30.9	34.3	36.1	38.4	42.5	47.4	51.7	56.0	65.6	77.7
49	28.1	30.5	31.7	35.1	37.0	39.3	43.5	48.5	52.9	57.3	67.0	79.3
50	28.9	31.3	32.5	36.0	37.9	40.3	44.5	49.6	54.0	58.5	68.5	81.0

N/B	0.01	0.05	0.1	0.5	1	2	5	10	15	20	30	40
51	29.6	32.1	33.3	36.9	38.8	41.2	45.5	50.6	55.2	59.8	69.9	82.7
52	30.4	32.9	34.2	37.7	39.7	42.1	46.5	51.7	56.4	61.0	71.3	84.3
53	31.2	33.7	35.0	38.6	40.6	43.1	47.5	52.8	57.5	62.2	72.7	86.0
54	31.9	34.5	35.8	39.5	41.5	44.0	48.5	53.9	58.7	63.5	74.2	87.7
55	32.7	35.3	36.6	40.4	42.4	44.9	49.5	55.0	59.8	64.7	75.6	89.3
56	33.5	36.1	37.5	41.2	43.3	45.9	50.5	56.1	61.0	65.9	77.0	91.0
57	34.3	37.0	38.3	42.1	44.2	46.8	51.6	57.1	62.1	67.2	78.4	92.6
58	35.1	37.8	39.1	43.0	45.1	47.8	52.6	58.2	63.3	68.4	79.9	94.3
59	35.8	38.6	40.0	43.9	46.0	48.7	53.6	59.3	64.5	69.7	81.3	96.0
60	36.6	39.4	40.8	44.8	47.0	49.6	54.6	60.4	65.6	70.9	82.7	97.6
61	37.4	40.2	41.6	45.6	47.9	50.6	55.6	61.5	66.8	72.1	84.1	99.3
62	38.2	41.1	42.5	46.5	48.8	51.5	56.6	62.6	68.0	73.4	85.6	101.0
63	39.0	41.9	43.3	47.4	49.7	52.5	57.6	63.7	69.1	74.6	87.0	102.6
64	39.8	42.7	44.2	48.3	50.6	53.4	58.6	64.8	70.3	75.9	88.4	104.3
65	40.6	43.5	45.0	49.2	51.5	54.4	59.6	65.8	71.4	77.1	89.8	106.0
66	41.4	44.4	45.9	50.1	52.4	55.3	60.6	66.9	72.6	78.4	91.3	107.6
67	42.2	45.2	46.7	51.0	53.4	56.3	61.6	68.0	73.8	79.6	92.7	109.3
68	43.0	46.0	47.5	51.9	54.3	57.2	62.6	69.1	74.9	80.8	94.1	111.0
69	43.8	46.9	48.4	52.8	55.2	58.2	63.7	70.2	76.1	82.1	95.5	112.6
70	44.6	47.7	49.2	53.7	56.1	59.1	64.7	71.3	77.3	83.3	97.0	114.3
71	45.4	48.5	50.1	54.6	57.0	60.1	65.7	72.4	78.4	84.6	98.4	116.0
72	46.2	49.4	50.9	55.5	58.0	61.0	66.7	73.5	79.6	85.8	99.8	117.6
73	47.0	50.2	51.8	56.4	58.9	62.0	67.7	74.6	80.8	87.1	101.2	119.3
74	47.8	51.0	52.7	57.3	59.8	63.0	68.7	75.7	81.9	88.3	102.7	120.9
75	48.6	51.9	53.5	58.2	60.7	63.9	69.7	76.7	83.1	89.5	104.1	122.6
76	49.4	52.7	54.4	59.1	61.7	64.9	70.8	77.8	84.3	90.8	105.5	124.3
77	50.2	53.6	55.2	60.0	62.6	65.8	71.8	78.9	85.4	92.0	106.9	125.9
78	51.1	54.4	56.1	60.9	63.5	66.8	72.8	80.0	86.6	93.3	108.4	127.6
79	51.9	55.3	57.0	61.8	64.4	67.7	73.8	81.1	87.7	94.5	109.8	129.3
80	52.7	56.1	57.8	62.7	65.4	68.7	74.8	82.2	88.9	95.8	111.2	130.9
81	53.5	57.0	58.7	63.6	66.3	69.7	75.8	83.3	90.1	97.0	112.6	132.6
82	54.3	57.8	59.5	64.5	67.2	70.6	76.9	84.4	91.2	98.2	114.1	134.3
83	55.2	58.7	60.4	65.4	68.2	71.6	77.9	85.5	92.4	99.5	115.5	135.9
84	56.0	59.5	61.3	66.3	69.1	72.5	78.9	86.6	93.6	100.7	116.9	137.6
85	56.8	60.4	62.1	67.2	70.0	73.5	79.9	87.7	94.7	102.0	118.3	139.3
86	57.6	61.2	63.0	68.1	71.0	74.5	80.9	88.8	95.9	103.2	119.8	140.9
87	58.4	62.1	63.9	69.0	71.9	75.4	82.0	89.9	97.1	104.5	121.2	142.6
88	59.3	62.9	64.7	69.9	72.8	76.4	83.0	91.0	98.3	105.7	122.6	144.3
89	60.1	63.8	65.6	70.8	73.8	77.3	84.0	92.1	99.4	107.0	124.0	145.9
90	60.9	64.6	66.5	71.8	74.7	78.3	85.0	93.2	100.6	108.2	125.5	147.6
91	61.8	65.5	67.4	72.7	75.6	79.3	86.0	94.2	101.8	109.4	126.9	149.3
92	62.6	66.4	68.2	73.6	76.6	80.2	87.1	95.3	102.9	110.7	128.3	150.9
93	63.4	67.2	69.1	74.5	77.5	81.2	88.1	96.4	104.1	111.9	129.8	152.6
94	64.3	68.1	70.0	75.4	78.4	82.2	89.1	97.5	105.3	113.2	131.2	154.3
95	65.1	68.9	70.9	76.3	79.4	83.1	90.1	98.6	106.4	114.4	132.6	155.9
96	65.9	69.8	71.7	77.2	80.3	84.1	91.2	99.7	107.6	115.7	134.0	157.6
97	66.8	70.7	72.6	78.2	81.3	85.1	92.2	100.8	108.8	116.9	135.5	159.3
98	67.6	71.5	73.5	79.1	82.2	86.0	93.2	101.9	109.9	118.2	136.9	160.9
99	68.4	72.4	74.4	80.0	83.1	87.0	94.2	103.0	111.1	119.4	138.3	162.6
100	69.3	73.3	75.2	80.9	84.1	88.0	95.2	104.1	112.3	120.6	139.7	164.3

Formulas:

Voltaje f - Voltaje i = G.

Potencia f - Potencia i = perdida

Potencia: $P[dB] = 10 \cdot \log_{10}\left(\frac{P_2[W]}{P_1[W]}(veces)\right)$

Tension: $T[dB] = 20 \cdot \log_{10}\left(\frac{P_2(veces)[V]}{P_1(veces)[V]}\right)$

} (W o V) a (DB)

Potencia: $10^{\frac{P(dB)}{10}} = W.$

Tension: $10^{\frac{T(dB)}{20}} = V$

} (DB) a (W o V)

FRIS: (veces)

$$Pr = \frac{Pt \cdot Gt \cdot Gr \cdot \lambda^2}{(4\pi)^2 d^2 \cdot L} \quad ; \quad \lambda = \frac{c}{f} \quad ; \quad PL = \left(\frac{4\pi d[m]}{\lambda}\right)^2$$

PIRE = Pentrada * Gananteatransmisora

FRIS: (dB)

$$Pr(dB) = Pt(dBm) + Gt(dB) + Gr[dB] - PL(dB) - L(dB)$$

PL simplificada:

$$Pr(d)(dBm) = 10\log\left(\frac{Prdo(mW)}{0,001W}\right) + 2 \cdot 10\log\left(\frac{do}{d}\right)$$

dos rayos:

$$Pr = \frac{Pt\,Gt\,Gr\,(hr\,ht)^2}{d^2}$$

$$Pr[dBm] = Pt(dBm) + 10\log_{10}(Gt\,Gr) + 20\log_{10}(ht\,hr) - 40\log_{10}(d)$$