

PROPAGATION FORMULAS

1.1 DBW FROM VOLTAGE OR POWER

$$\text{Power in dBW} = 10 \text{ Log} \left(\frac{(\text{Voltage in microvolts} \times 10^{-6})^2}{50 \text{ ohms}} \right)$$

$$\text{Power in dBW} = 10 \text{ Log} \left(\frac{(\text{Voltage in volts})^2}{50 \text{ ohms}} \right)$$

$$\text{Power in dBW} = 10 \text{ Log} (\text{Power in watts})$$

Note: dBW = dBm - 30 dB

1.2 FREQUENCY TO WAVELENGTH

$$\text{Wavelength in Meters} = \frac{300}{f_{\text{MHz}}}$$

$$\text{Wavelength in Feet} = \frac{984}{f \text{ MHz}}$$

1.3 FREE SPACE LOSS

$$\text{Half Wave Dipole (distance in miles)} \quad \text{dB} = 32.28 + 20 \text{ LOG } f_{\text{MHz}} + 20 \text{ LOG } D_{\text{mi}}$$

$$\text{Isotropic radiator (distance in miles)} \quad \text{dB} = 36.58 + 20 \text{ LOG } f_{\text{MHz}} + 20 \text{ LOG } D_{\text{mi}}$$

$$\text{Half Wave Dipoles (distance in Kilometers)} \quad \text{dB} = 88.15 + 20 \text{ LOG } f_{\text{GHz}} + 20 \text{ LOG } D_{\text{km}}$$

Isotropic radiator (distance in kilometers) $dB = 92.45 + 20 \text{ LOG } f_{\text{GHz}} + 20 \text{ LOG } D_{\text{km}}$

1.4 EARTH CURVATURE

	<u>d in miles, h in feet</u>	<u>d in kilometers, h in meters</u>
General	$h = \frac{d_1 d_2}{1.5K}$	$h = \frac{d_1 d_2}{12.75K}$
$K = \infty$	$h = 0$	$h = 0$
$K = 4/3$	$h = \frac{d_1 d_2}{2}$	$h = \frac{d_1 d_2}{17}$
$K = 2/3$	$h = d_1 d_2$	$h = \frac{d_1 d_2}{8.5}$
$K = 1$	$h = 0.67 d_1 d_2$	$h = \frac{d_1 d_2}{12.75}$

Where h = the change in vertical distance from a horizontal reference line, in feet/meters

d_1 = the distance from a point to one end of the path in miles/kilometers

d_2 = the distance from the same point to the other end of the path, in miles/kilometers

K = the equivalent earth radius factor

1.5 FRESNEL ZONE

Feet $F_1 = 72.1 \sqrt{\frac{d_1 d_2}{(f_{\text{GHz}})D}}$ d_1, d_2, D in miles

Meters $F_1 = 17.3 \sqrt{\frac{d_1 d_2}{(f_{\text{GHz}})D}}$ d_1, d_2, D in kilometers

Where: F_1 = first Fresnel zone radius in feet/meters

d_1 = distance from one end of path to reflection point

$d_2 = D - d_1$

D = Total length of path

f = frequency in GHz

Note: These formulas provide the distance to the first Fresnel Zone. If "0.6" Fresnel is required then multiply by "0.6".

1.6 DISTANCE TO RADIO HORIZON

$$\text{General} \quad D = \sqrt{\frac{3Kh}{2}}$$

$$K=1 \quad D = \sqrt{1.5h}$$

$$K = 4/3 \quad D = \sqrt{2h}$$

Where: D = distance to the radio horizon in miles
 K = the equivalent earth radius factor
 h = height in feet

1.7 FIELD STRENGTH TO SENSITIVITY

$$uV = \frac{39.5 * (uV / m)}{f_{\text{MHz}}}$$

$$F_{\text{dBuV / m}} = 20 \text{ Log } E_{(uV / m)}$$

$$F_{\text{dBuV / m}} = 105 + 10 \text{ Log } P_{(\text{Watts})} + 20 \text{ Log}(f_{\text{MHz}})$$

$$F_{\text{dBuV / m}} = 75 + 10 \text{ Log } P_{(\text{milliWatts})} + 20 \text{ Log}(f_{\text{MHz}})$$

$$\frac{\text{dBW}}{\text{m}^2} = \text{dBm} - 70.65 + 20 \text{ Log}(f_{\text{MHz}})$$

Where F = field strength in dB microvolts per meter

P = power

f = frequency

Note: For 50 ohms, referenced to a dipole.

1.8 DOPPLER SHIFT

$$v(\text{km / h}) = 1079 * \frac{\Delta f_{\text{Hz}}}{f_{\text{MHz}}}$$

$$\Delta f_{\text{Hz}} = 0.009266 * v(\text{km / h}) * f_{\text{MHz}}$$

$$v(\text{m / h}) = 670.6 * \frac{\Delta f_{\text{Hz}}}{f_{\text{MHz}}}$$

$$\Delta f_{\text{Hz}} = 0.00149 * v(\text{m / h}) * f_{\text{MHz}}$$

Where v = velocity

1.9 NEAR FIELD / FAR FIELD BOUNDARY

$$\text{Far Field Starts at: } \frac{983}{f_{\text{MHz}}} * 10^{\frac{G_{\text{dBd}}}{10}} \text{ (meters)}$$

$$\text{Far Field Starts at: } \frac{3226}{f_{\text{MHz}}} * 10^{\frac{G_{\text{dBd}}}{10}} \text{ (feet)}$$

Where: G_{dBd} = Gain referenced to a dipole

1.10 NOISE POWER

$$P_{\text{N(Watts)}} = kTB$$

Where: k = Boltzman's constant = $1.38 * 10^{-23} \frac{J}{K}$

B = Bandwidth in Hz

T = 290 Kelvin

Noise power in dBm is $P_{\text{N}} = -143.9 + 10\text{Log}(B_{\text{kHz}})$

FORMULA REFERENCES:

1-1 Engineering Considerations for Microwave Communications Systems, Fourth Edition, GTE Lenkurt Inc., 1975

MICROVOLT TO dBW and dBm

Microvolt	dBW	dBm	Microvolt	dBW	dBm	Microvolt	dBW	dBm
0.10	-156.99	-126.99	0.58	-141.72	-111.72	1.06	-136.48	-106.48
0.11	-156.16	-126.16	0.59	-141.57	-111.57	1.07	-136.40	-106.40
0.12	-155.41	-125.41	0.60	-141.43	-111.43	1.08	-136.32	-106.32
0.13	-154.71	-124.71	0.61	-141.28	-111.28	1.09	-136.24	-106.24
0.14	-154.07	-124.07	0.62	-141.14	-111.14	1.10	-136.16	-106.16
0.15	-153.47	-123.47	0.63	-141.00	-111.00	1.11	-136.08	-106.08
0.16	-152.91	-122.91	0.64	-140.87	-110.87	1.12	-136.01	-106.01
0.17	-152.38	-122.38	0.65	-140.73	-110.73	1.13	-135.93	-105.93
0.18	-151.88	-121.88	0.66	-140.60	-110.60	1.14	-135.85	-105.85
0.19	-151.41	-121.41	0.67	-140.47	-110.47	1.15	-135.78	-105.78
0.20	-150.97	-120.97	0.68	-140.34	-110.34	1.16	-135.70	-105.70
0.21	-150.55	-120.55	0.69	-140.21	-110.21	1.17	-135.63	-105.63
0.22	-150.14	-120.14	0.70	-140.09	-110.09	1.18	-135.55	-105.55
0.23	-149.76	-119.76	0.71	-139.96	-109.96	1.19	-135.48	-105.48
0.24	-149.39	-119.39	0.72	-139.84	-109.84	1.20	-135.41	-105.41
0.25	-149.03	-119.03	0.73	-139.72	-109.72	1.21	-135.33	-105.33
0.26	-148.69	-118.69	0.74	-139.61	-109.61	1.22	-135.26	-105.26
0.27	-148.36	-118.36	0.75	-139.49	-109.49	1.23	-135.19	-105.19
0.28	-148.05	-118.05	0.76	-139.37	-109.37	1.24	-135.12	-105.12
0.29	-147.74	-117.74	0.77	-139.26	-109.26	1.25	-135.05	-105.05
0.30	-147.45	-117.45	0.78	-139.15	-109.15	1.26	-134.98	-104.98
0.31	-147.16	-117.16	0.79	-139.04	-109.04	1.27	-134.91	-104.91
0.32	-146.89	-116.89	0.80	-138.93	-108.93	1.28	-134.85	-104.85
0.33	-146.62	-116.62	0.81	-138.82	-108.82	1.29	-134.78	-104.78
0.34	-146.36	-116.36	0.82	-138.71	-108.71	1.30	-134.71	-104.71
0.35	-146.11	-116.11	0.83	-138.61	-108.61	1.31	-134.64	-104.64
0.36	-145.86	-115.86	0.84	-138.50	-108.50	1.32	-134.58	-104.58
0.37	-145.63	-115.63	0.85	-138.40	-108.40	1.33	-134.51	-104.51
0.38	-145.39	-115.39	0.86	-138.30	-108.30	1.34	-134.45	-104.45
0.39	-145.17	-115.17	0.87	-138.20	-108.20	1.35	-134.38	-104.38
0.40	-144.95	-114.95	0.88	-138.10	-108.10	1.36	-134.32	-104.32
0.41	-144.73	-114.73	0.89	-138.00	-108.00	1.37	-134.26	-104.26
0.42	-144.52	-114.52	0.90	-137.90	-107.90	1.38	-134.19	-104.19
0.43	-144.32	-114.32	0.91	-137.81	-107.81	1.39	-134.13	-104.13
0.44	-144.12	-114.12	0.92	-137.71	-107.71	1.40	-134.07	-104.07
0.45	-143.93	-113.93	0.93	-137.62	-107.62	1.41	-134.01	-104.01
0.46	-143.73	-113.73	0.94	-137.53	-107.53	1.42	-133.94	-103.94
0.47	-143.55	-113.55	0.95	-137.44	-107.44	1.43	-133.88	-103.88
0.48	-143.36	-113.36	0.96	-137.34	-107.34	1.44	-133.82	-103.82
0.49	-143.19	-113.19	0.97	-137.25	-107.25	1.45	-133.76	-103.76
0.50	-143.01	-113.01	0.98	-137.17	-107.17	1.46	-133.70	-103.70
0.51	-142.84	-112.84	0.99	-137.08	-107.08	1.47	-133.64	-103.64
0.52	-142.67	-112.67	1.00	-136.99	-106.99	1.48	-133.58	-103.58
0.53	-142.50	-112.50	1.01	-136.90	-106.90	1.49	-133.53	-103.53

0.54	-142.34	-112.34	1.02	-136.82	-106.82	1.50	-133.47	-103.47
0.55	-142.18	-112.18	1.03	-136.73	-106.73	1.51	-133.41	-103.41
0.56	-142.03	-112.03	1.04	-136.65	-106.65	1.52	-133.35	-103.35
0.57	-141.87	-111.87	1.05	-136.57	-106.57	1.53	-133.30	-103.30
1.54	-133.24	-103.24	2.01	-130.93	-100.93	2.48	-129.10	-99.10
1.55	-133.18	-103.18	2.02	-130.88	-100.88	2.49	-129.07	-99.07
1.56	-133.13	-103.13	2.03	-130.84	-100.84	2.50	-129.03	-99.03
1.57	-133.07	-103.07	2.04	-130.80	-100.80	2.51	-129.00	-99.00
1.58	-133.02	-103.02	2.05	-130.75	-100.75	2.52	-128.96	-98.96
1.59	-132.96	-102.96	2.06	-130.71	-100.71	2.53	-128.93	-98.93
1.60	-132.91	-102.91	2.07	-130.67	-100.67	2.54	-128.89	-98.89
1.61	-132.85	-102.85	2.08	-130.63	-100.63	2.55	-128.86	-98.86
1.62	-132.80	-102.80	2.09	-130.59	-100.59	2.56	-128.82	-98.82
1.63	-132.75	-102.75	2.10	-130.55	-100.55	2.57	-128.79	-98.79
1.64	-132.69	-102.69	2.11	-130.50	-100.50	2.58	-128.76	-98.76
1.65	-132.64	-102.64	2.12	-130.46	-100.46	2.59	-128.72	-98.72
1.66	-132.59	-102.59	2.13	-130.42	-100.42	2.60	-128.69	-98.69
1.67	-132.54	-102.54	2.14	-130.38	-100.38	2.61	-128.66	-98.66
1.68	-132.48	-102.48	2.15	-130.34	-100.34	2.62	-128.62	-98.62
1.69	-132.43	-102.43	2.16	-130.30	-100.30	2.63	-128.59	-98.59
1.70	-132.38	-102.38	2.17	-130.26	-100.26	2.64	-128.56	-98.56
1.71	-132.33	-102.33	2.18	-130.22	-100.22	2.65	-128.52	-98.52
1.72	-132.28	-102.28	2.19	-130.18	-100.18	2.66	-128.49	-98.49
1.73	-132.23	-102.23	2.20	-130.14	-100.14	2.67	-128.46	-98.46
1.74	-132.18	-102.18	2.21	-130.10	-100.10	2.68	-128.43	-98.43
1.75	-132.13	-102.13	2.22	-130.06	-100.06	2.69	-128.39	-98.39
1.76	-132.08	-102.08	2.23	-130.02	-100.02	2.70	-128.36	-98.36
1.77	-132.03	-102.03	2.24	-129.98	-99.98	2.71	-128.33	-98.33
1.78	-131.98	-101.98	2.25	-129.95	-99.95	2.72	-128.30	-98.30
1.79	-131.93	-101.93	2.26	-129.91	-99.91	2.73	-128.27	-98.27
1.80	-131.88	-101.88	2.27	-129.87	-99.87	2.74	-128.23	-98.23
1.81	-131.84	-101.84	2.28	-129.83	-99.83	2.75	-128.20	-98.20
1.82	-131.79	-101.79	2.29	-129.79	-99.79	2.76	-128.17	-98.17
1.83	-131.74	-101.74	2.30	-129.76	-99.76	2.77	-128.14	-98.14
1.84	-131.69	-101.69	2.31	-129.72	-99.72	2.78	-128.11	-98.11
1.85	-131.65	-101.65	2.32	-129.68	-99.68	2.79	-128.08	-98.08
1.86	-131.60	-101.60	2.33	-129.64	-99.64	2.80	-128.05	-98.05
1.87	-131.55	-101.55	2.34	-129.61	-99.61	2.81	-128.02	-98.02
1.88	-131.51	-101.51	2.35	-129.57	-99.57	2.82	-127.98	-97.98
1.89	-131.46	-101.46	2.36	-129.53	-99.53	2.83	-127.95	-97.95
1.90	-131.41	-101.41	2.37	-129.49	-99.49	2.84	-127.92	-97.92
1.91	-131.37	-101.37	2.38	-129.46	-99.46	2.85	-127.89	-97.89
1.92	-131.32	-101.32	2.39	-129.42	-99.42	2.86	-127.86	-97.86
1.93	-131.28	-101.28	2.40	-129.39	-99.39	2.87	-127.83	-97.83
1.94	-131.23	-101.23	2.41	-129.35	-99.35	2.88	-127.80	-97.80
1.95	-131.19	-101.19	2.42	-129.31	-99.31	2.89	-127.77	-97.77
1.96	-131.14	-101.14	2.43	-129.28	-99.28	2.90	-127.74	-97.74
1.97	-131.10	-101.10	2.44	-129.24	-99.24	2.91	-127.71	-97.71
1.98	-131.06	-101.06	2.45	-129.21	-99.21	2.92	-127.68	-97.68
1.99	-131.01	-101.01	2.46	-129.17	-99.17	2.93	-127.65	-97.65
2.00	-130.97	-100.97	2.47	-129.14	-99.14	2.94	-127.62	-97.62

