Key Equations:

1. $c = \lambda F \sqrt{\in}$

2. $\lambda = \frac{c}{F\sqrt{\in}}$

3. $F = \frac{c}{\lambda\sqrt{\in}}$

4. $T = \frac{1}{F}$

5. $\delta = \sqrt{\frac{1}{2\pi F \sigma \mu}}$

Microwave Transmission Lines:

6. Impedance inversion in a quarter-wavelength shorted stub: $\frac{Z}{Z_o} = \frac{Z_o}{Z_L}$

7. Characteristic impedance for a quarter-wavelength Q section: $Z_o = \sqrt{ZZ_L}$

8. VSWR:
   From incident voltage (Vi) and reflected voltage (Vr): $VSWR = \frac{V_i + V_r}{V_i - V_r}$

9. Length of a transmission line as a function of reflection transit time: $L_{meters} = \frac{c\upsilon T_d}{2}$

10. Impedance looking in to a transmission line:
    (a) ZL is not equal to Zo in a random-length lossy line: $Z = Z_o \frac{Z_L + Z_o \tan(\gamma l)}{Z_o + Z_L \tan(\gamma l)}$

    (b) Half-wavelength lossy lines: $Z_o = \frac{276}{\sqrt{\varepsilon}} \log \frac{2S}{d}$

11. Characteristic impedance of transmission lines:
    (a) Parallel line:
    $$Z_o = \frac{276}{\sqrt{\varepsilon}} \log \frac{2S}{d}$$
    (b) Coaxial line:
    $$Z_o = \frac{138}{\sqrt{\varepsilon}} \log \frac{D}{d}$$
    (c) Stripline:
    $$Z_o = \frac{377}{\sqrt{\varepsilon}} \frac{T}{W}$$

12. Transmission line impedance as a function of voltage and current: $Z_L = \frac{V_{inc} + V_{ref}}{I_{inc} + I_{ref}}$

13. Characteristic impedance of a lossy line: $\sqrt{\frac{R + j\omega L}{G + j\omega C}}$

14. Dielectric constant as a function of velocity: $\varepsilon = \frac{1}{\upsilon^2}$

15. Cutoff wavelength: $\lambda_c = \frac{2}{\sqrt{(m/a)^2 (n/b)^2}}$

16. Propagation constant as a function of frequency: $\beta = \omega\sqrt{\varepsilon\mu} \quad \sqrt{1 - \left(\frac{F_c}{F}\right)^2}$

Waveguides:

17. Group velocity in a waveguide: $V_g = c \sin a$

18. Relationship between frequency and free-space wavelength: $c = F\lambda_o$

19. Wavelength in a waveguide: $\lambda = \frac{V_p \lambda_o}{c}$

20. Cutoff wavelength: $\lambda = 2a$

21. Cutoff frequency: $F_c = \frac{C}{2a}$

22. Complex impedance: $Z = R \pm jX$

23. Normalized impedance: $Z = \frac{R \pm jX}{Z_o}$

24. Power reflection coefficient: $P_{pwr} = P^2$

25. VSWR as a function of reflection coefficient: $VSWR = \frac{1+P}{1-P}$

26. Return loss as a function of VSWR: $Loss_{ret} = 10\log(P_{pwr})$

27. General mode equation for resonant cavity: $F_r = \frac{c}{2(\mu\varepsilon)}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 = \left(\frac{P}{d}\right)^2}$

28. Mode equation for air dielectric: $F_r = \frac{c}{2}\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2 = \left(\frac{P}{d}\right)^2}$

29. Quality factor Q of a resonant circuit: $Q_0 = \frac{2\pi\ U_s}{U_d}$

Microwave Antennas:

30. Shape factor: $SF = \frac{F2 - F1}{F_H - F_L}$

31. Q of a filter: $Q = \frac{F_c}{BW_{3dB}}$

32. Cutoff frequency of a waveguide feeding dish antenna: $f_{cutoff} = \frac{175{,}698}{d_{mm}}$

33. Gain of a parabolic dish antenna: $G = \frac{k(\pi D)^2}{\lambda^2}$

34. Focal length of parabolic dish antenna: $f = \frac{D^2}{16d}$

35. Antenna directivity as a function of power densities: $D = \frac{P_{\max}}{P_{av}}$

36. Directivity gain of an antenna: $G_d = \frac{4\pi P_a}{P_r}$

37. Power gain of an antenna: $G_p = \frac{4\pi P_a}{P_n}$

38. Relationship between directivity gain and power gain: $G_p = \frac{P_r G_d}{P_n}$

39. Gain of a horn radiator: $G = \frac{10A}{\lambda^2}$

40. Alternate notations for impedance in ac circuits: $Z = \sqrt{R^2 + \left(X_L - Xc^2\right)}$

41. Efficiency factor of an antenna comparing resistances: $k = \dfrac{R_r}{R_r + R_o}$

Microwave Transistors:

42. Power-frequency limit: $\dfrac{\sqrt{P_{\max} X_{co}}}{2\pi (l/\upsilon)} = \dfrac{E_{\max} V_s}{2\pi}$

43. Maximum gain: $G_{\max} = \sqrt{\dfrac{F_t}{F}} \dfrac{Z_o}{Z_{in}}$

Discrete Microwave Amplifiers:

44. Gain of a parametric amplifier: $G = f_i / f_s$

45. Noise in a parametric amplifier: $F_{noise} = \dfrac{R_a}{R1} + \dfrac{f_s}{f_i}$

46. Manley-Rowe relationship for parametric amplifiers: $\sum_{m,n} \dfrac{mP_{m,n}}{mf_p + nf_s} = 0$

47. Noise figure as a function of noise factor: $NF = 10 \log F_n$

48. Noise temperature as a function of noise factor: $T_e = (F_n - 1)T_0$

49. Noise temperature as a function of noise figure: $T_e = \left[anti \log\left(\dfrac{NF}{10}\right) - 1 \right] KT_0$

50. Total noise in a system: $P_{n(total)} = GKB(T_o + T_e)$

51. Noise factor of amplifiers in cascade: $F_n = F_1 + \dfrac{F_2 - 1}{G1} + \dfrac{F_3 - 1}{G1G2} + \text{K} + \dfrac{F_n - 1}{G1G2\,\text{K}\;G_{n-1}}$

52. Characteristic impedance required of a quarter-wave Q-section transformer:

$$Z_o = \sqrt{R_i \times R_o}$$

Hybrid and Monolithic Microwave Integrated Circuit Amplifiers:

53. Noise power: $P_n = KTB$

54. Noise factor as a function of SNR: $F_n = \frac{SNR_{in}}{SNR_{out}}$

55. Noise factor as a function of output noise power: $F_n = \frac{P_{no}}{KT_0BG}$

56. Component values in the LC version of the Wilkinson power divider:

$$R = 2Z_o$$

$$L = \frac{70.7}{2\pi F_o}$$

$$C = \frac{1}{2\pi 70.7 F_o}$$

57. Physical length of a quarter-wavelength coaxial cable section: $L = \frac{2952V}{F}$

58. Impedance required of a quarter-wavelength Q matching section: $Z'_o = \sqrt{Z_L Z_O}$

59. Characteristic impedance of a stripline section: $Z_o = 377\frac{h}{w\sqrt{\varepsilon}}$

60. Input/output impedance of MIC internal amplifier: $R_o = \sqrt{R_f \times R_e}$

61. Gain in MIC internal amplifier: $G_{dB} = 20 \log\left[\frac{R_f - R_e}{R_o = R_e}\right]$

62. Gain in a cascade amplifier: $G = G1 \times G2 \times G3 \times \mathsf{K} \times Gn$

63. Mismatch loss due to SWR in a single-stage amplifier: $ML = -10 \log\left[1 - \left(\frac{SWR-1}{SWR+1}\right)^2\right]$

64. Noise figure of a cascade amplifier: $NF_{total} = NF1 + \frac{NF2-1}{G1} + \frac{NF3-1}{G1G2} + \mathsf{K} + \frac{NFn-1}{G1G2Gn}$

Microwave Diodes:

65. Tunnel diode frequencies - self-resonant frequency: $F_s = \frac{1}{2\pi}\sqrt{\frac{1}{L_s C_j} - \frac{1}{(RC_j)^2}}$

Microwave Diode Generators:

66. Electron transit time in a Gunn diode: $T_t = \frac{L}{V_\delta}$

67. Operating frequency in the Gunn or transit-time mode: $F_o = \frac{V_{dom}}{L_{eff}}$

68. Criterion for LSA oscillation: $-G \geq G_o$

69. Output power from a Gunn diode: $P_o = n(MV_{th}L)(N_o eVA)$

Transmitters:

70. Output frequency of a multiplier: $F2 = N \times F1$

71. Friis's transmission equation: $\frac{P_r}{P_t} = \frac{G_t G_r \lambda^2}{(4\pi d)^2}$

72. Friis's equation in decibel form: $10 \log \frac{P_r}{P_t} = G_{t(dB)} + G_{r(dB)} + 10 \log\left(\frac{\lambda}{4\pi d}\right)^2$

73. Spreading loss in satellite communications: $L = 33\,dB + [20 \log (d_{km})] + [20 \log (F_{MHZ})]$

74. Total noise in system: $T_{total} = T_{eq(rcvr)} + T_{eq(ant)}$

PROPAGATION FORMULAS

1.1 DBW FROM VOLTAGE OR POWER

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

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

Power in dBW = 10 Log (Power in watts)

Note: dBW = dBm - 30 dB

1.2 FREQUENCY TO WAVELENGTH

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

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

1.3 FREE SPACE LOSS

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

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

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

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

1.4 EARTH CURVATURE

	d in miles, h in feet	d in kilometers, h in meters
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 $F_1 = 72.1 \sqrt{\frac{d_1 d_2}{(f_{GHz})D}}$ d_1, d_2, D in miles

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

$d2 = D - d_1$

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

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

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

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

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

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

$$F_{\text{dB}u\text{V} / \text{m}} = 20 \text{ Log } E_{(u\text{V} / \text{m})}$$

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

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

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

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

$$v_{(km/h)} = 1079 * \frac{\Delta f_{Hz}}{f_{MHz}} \qquad v_{(m/h)} = 670.6 * \frac{\Delta f_{Hz}}{f_{MHz}}$$

$$\Delta f_{Hz} = 0.009266 * v_{(km/h)} * f_{MHz} \qquad \Delta f_{Hz} = 0.00149 * v_{(m/h)} * f_{MHz}$$

Where v = velocity

1.9 NEAR FIELD / FAR FIELD BOUNDARY

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

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

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

1.10 NOISE POWER

$P_{N(Watts)} = kTB$

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

B = Bandwidth in Hz

T = 290 Kelvin

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

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

Power Conversion Table

dBm	watts	dBm	watts	dBm	watts	dBm	watts	dBm	watts
30.0	1.00	38.0	6.31	46.0	39.81	54.0	251	62.0	1585
30.2	1.05	38.2	6.61	46.2	41.69	54.2	263	62.2	1660
30.4	1.10	38.4	6.92	46.4	43.65	54.4	275	62.4	1738
30.6	1.15	38.6	7.24	46.6	45.71	54.6	288	62.6	1820
30.8	1.20	38.8	7.59	46.8	47.86	54.8	302	62.8	1905
31.0	1.26	39.0	7.94	47.0	50.12	55.0	316	63.0	1995
31.2	1.32	39.2	8.32	47.2	52.48	55.2	331	63.2	2089
31.4	1.38	39.4	8.71	47.4	54.95	55.4	347	63.4	2188
31.6	1.45	39.6	9.12	47.6	57.54	55.6	363	63.6	2291
31.8	1.51	39.8	9.55	47.8	60.26	55.8	380	63.8	2399
32.0	1.58	40.0	10.00	48.0	63.10	56.0	398	64.0	2512
32.2	1.66	40.2	10.47	48.2	66.07	56.2	417	64.2	2630
32.4	1.74	40.4	10.96	48.4	69.18	56.4	437	64.4	2754
32.6	1.82	40.6	11.48	48.6	72.44	56.6	457	64.6	2884
32.8	1.91	40.8	12.02	48.8	75.86	56.8	479	64.8	3020
33.0	2.00	41.0	12.59	49.0	79.43	57.0	501	65.0	3162
33.2	2.09	41.2	13.18	49.2	83.18	57.2	525	65.2	3311
33.4	2.19	41.4	13.80	49.4	87.10	57.4	550	65.4	3467
33.6	2.29	41.6	14.45	49.6	91.20	57.6	575	65.6	3631
33.8	2.40	41.8	15.14	49.8	95.50	57.8	603	65.8	3802
34.0	2.51	42.0	15.85	50.0	100	58.0	631	66.0	3981
34.2	2.63	42.2	16.60	50.2	105	58.2	661	66.2	4169
34.4	2.75	42.4	17.38	50.4	110	58.4	692	66.4	4365
34.6	2.88	42.6	18.20	50.6	115	58.6	724	66.6	4571
34.8	3.02	42.8	19.05	50.8	120	58.8	759	66.8	4786
35.0	3.16	43.0	19.95	51.0	126	59.0	794	67.0	5012
35.2	3.31	43.2	20.89	51.2	132	59.2	832	67.2	5248
35.4	3.47	43.4	21.88	51.4	138	59.4	871	67.4	5495
35.6	3.63	43.6	22.91	51.6	145	59.6	912	67.6	5754
35.8	3.80	43.8	23.99	51.8	151	59.8	955	67.8	6026
36.0	3.98	44.0	25.12	52.0	158	60.0	1000	68.0	6310
36.2	4.17	44.2	26.30	52.2	166	60.2	1047	68.2	6607
36.4	4.37	44.4	27.54	52.4	174	60.4	1096	68.4	6918
36.6	4.57	44.6	28.84	52.6	182	60.6	1148	68.6	7244
36.8	4.79	44.8	30.20	52.8	191	60.8	1202	68.8	7586
37.0	5.01	45.0	31.62	53.0	200	61.0	1259	69.0	7943
37.2	5.25	45.2	33.11	53.2	209	61.2	1318	69.2	8318
37.4	5.50	45.4	34.67	53.4	219	61.4	1380	69.4	8710
37.6	5.75	45.6	36.31	53.6	229	61.6	1445	69.6	9120
37.8	6.03	45.8	38.02	53.8	240	61.8	1514	69.8	9550
								70.0	10000

Frequency vs. Wavelength

Frequency	Wavelength
1 MHz	300 meters (m)
10 MHz	30 m
100 MHz	3 m
300 MHz	1 m --- 100 centimeters (cm)
1 GHz	30 cm
10 GHz	3 cm
100 GHz	3 millimeters (mm)
300 GHz	1 mm --- 10-3 m
3 x 1014	1 micron --- 10-6 m

Metric Prefixes

Metric Prefix	Multiplying Factor	Symbol
tera	10^{12}	T
giga	10^{9}	G
mega	10^{6}	M
kilo	10^{3}	K
hecto	10^{2}	h
deka	10	da
deci	10^{-1}	d
centi	10^{-2}	c
milli	10^{-3}	m
micro	10^{-6}	m
nano	10^{-9}	n
pico	10^{-12}	p
femto	10^{-15}	f
atto	10^{-18}	a

Conversion factors

1	inch	=	2.54 cm
1	inch	=	25.4 mm
1	foot	=	0.305 m
1	mile	=	1.61 km
1	nautical mile	=	6080 ft
1	statute mile	=	5280 ft
1	mil	=	2.54 x 10-5 m
1	kg	=	2.2 lb
1	neper	=	8.686 dB
1	gauss	=	10,000 teslas

Units

Quantity	Unit	Symbol
Capacitance	farad	F
Electric charge	coulomb	Q
Conductance	mhos (siemans)	Ω
Conductivity	mhos/meter	Ω/m
Current	ampere	A
Energy	joule (watt-sec)	J
Field	volts/meter	E
Flux linkage	weber (volt-second)	ψ
Frequency	hertz	Hz
Inductance	Henry	H
Length	meter	m
Mass	gram	g
Power	watt	W
Resistance	ohm	Ω
Time	second	s
Velocity	meter/second	m/s
Electric potential	volt	V

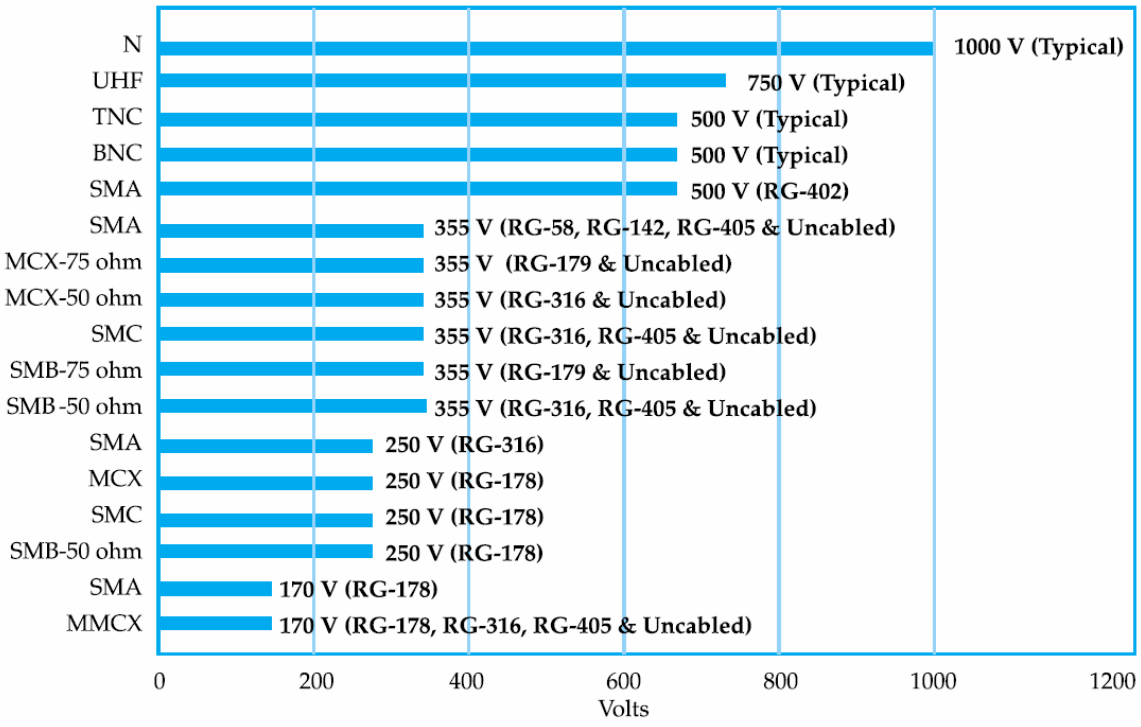
Physical constants

Constant	Value	Symbol
Boltzmann's constant	1.38 x 10^{-23} J/K	K
Electric charge (e-)	1.6 x 10^{-19} C	q
Electron (volt)	1.6 x 10^{-19} J	eV
Electron (mass)	9.12 x 10^{-31}kg	m
Permeability of free space	4p x 10^{-7} H/m	Yo
Permittivity of free space	8.85 x 10^{-12} F/m	∈o
Planck's constant	6.626 x 10^{-34} J û s	h
Velocity of electromagnetic waves	3 x 108 m/s	c
Pi (π)	3.1416	π

The Greek Alphabet and Its Engineering Uses

Name	Upper Case	Lower Case	Uses
Alpha	A	α	Absorption factor, angles, angular acceleration, attenuation constant, common-base currentam plifition factor, deviation of state parameter, temperature coef ficient of resistance, ther mal-expansion coefficient, thermal diffusivity
Beta	B	β	Angles, common-emitter current-amplification factor, flux density, phase constant, wavelength costant
Gamma	Γ	γ	Electrical conductivity, Grueneisen parameter
Delta	Δ	δ	Angles, damping coefficient (decay constant), decre ment, increment, secondary-emission ratio
Epsilon	E	ε	Capacitivity, dielectric coefficient, electric field intensity, electron energy, emmissivity, permit tivity, base of natural logarithms (2.7128)
Zeta	Z	ζ	Coefficients, coordinates, impedance
Eta	H	η	Chemical potential, dielectric susceptibility (intrin sic capacitance), efficiency, hysteresis, intrinsic impedance of a medium, intrinsic standoff ratio
Theta	Θ	θ	Angle of rotation, angles, angular phase dis placement, reluctance, thermal resistance, transit angle
Iota	I	ι	Inertia
Kappa	K	κ	Coupling coefficient, susceptibility
Lambda	Λ	λ	Line density of charge, permanence, photosensi- tivity, wavelength
Mu	M	μ	Amplification factor, magnetic permeability, micron, mobility, permeability, prefix micro
Nu	N	ν	Reflectivity
Xi	Ξ	ξ	Output coefficient
Omicron	O	o	
Pi	Π	π	Peltier coefficient, ratio of circumference to diameter (3.1416)
Rho	P	ρ	Reflection coefficient, reflection factor, resistivity, volume density of electric charge
Sigma	Σ	σ	Conductivity, Stefan-Boltzmann constant, summation, surface density of charge
Tau	T	τ	Period, propagation constant,. Thomson coefficient, time constant, time-phase displacement, transmission factor
Upsilon	Y	υ	Admittance
Phi	Φ	ϕ	Angles, coefficient of performance, contact potential, magnetic flux, phase angle, phase displacement, radi- ant flux
Chi	X	χ	Angles
Psi	Ψ	ψ	Angles, dielectric flux, displacement flux, phase difference
Omega	Ω	ω	Angular frequency, angular velocity, Ohms, resistance, solid angle

Maximum Rated Working Voltage



Maximum Rated Operating Frequency