ANTENNA THEORY

Symbols:

Π ≅ α ϕ λ ≤ ≠ ≥ ± θ Ω

Circumference of a circle = $2\prod r$
Surface of sphere = $4\prod r^2$
Volume = $(4/3)\prod r^3$
E = volts/m
H = A/m
S = W/m^2 = power density
Impedance of free space = 377 ohms
G = gain ratio = P2/P1 = 10**(GdB/10)
GdB = 10Log (P2/P1)
DBic = circular polarization; dBid = dBi + 2.2 = reference to a dipole
Fuel vapor hazard = S = $5W/cm^2$ = $50{,}000W/m^2$ = $5{,}000mW/cm^2$ **[using peak power]**

For **3dB**, G = 2 = 10**0.3 = surface of sphere/surface of hemisphere = $(4\prod r^2) / (2\prod r^2)$

S = (power density at distance r) = $PG/ (4\prod r^2)$

$S = E^2/377 = 377\ H^2$

Note: $PG/ (4\prod r^2)$ represents the **maximum S** for aperture antennas (i.e. the near field requires a gain reduction).

$Gr = 4\prod Ar/\lambda^2$; therefore, $\mathbf{Ar = Gr\lambda^2/4\prod}$ = the effective aperture area of the receive antenna

$S = PGt/ (4\prod r^2) = W/m^2$

So, $S(Ar) = (W/m^2)m^2 = W = PtGtGr\lambda^2/ (4\prod^2)(r^2) = Pr$

And $Pr/Pt = GtGr\lambda^2/ (4\prod^2)(r^2)$ which is a unitless expression.

And $10\log Pr - 10\log Pt = Gt + Gr + 20\log\lambda - 20\log 4\prod - 20\log r$ {Note: Gt & Gr are now in dB}

So $Pr = Pt + Gt + Gr + 20\log\lambda - 20\log 4\prod - 20\log r$

{Note: **10logP = dBW**, referenced to 1W. However, **10log1000P = dBm**, referenced to 1mW.}

Since $c = f\lambda$ and $\lambda = c/f$ and $\lambda^2 = c^2/f^2$

$$Pr = Pt + Gt + Gr + 20\log(c) - 20\log(f) - 20\log(4\Pi) - 20\log(r)$$

Or $$Pr = Pt + Gt + Gr + 20\log(c) - 20\log(f\ \text{MHz}) - 20\log(10^{6}) - 20\log(4\Pi) - 20\log(r)$$

$$Pr = Pt + Gt + Gr + 169.5 - 20\log(f\ \text{MHz}) - 120 - 22 - 20\log(r)$$

$$\mathbf{Pr = 27.5 + Pt + Gt + Gr - 20\log(f\ MHz) - 20\log(r)}$$ {r = meters, P = dBW or dBm, f = MHz}

$$\mathbf{Pr = 37.82 + Pt + Gt + Gr - 20\log(f\ MHz) - 20\log(r)}$$ {r = feet *0.3048m/ft}

$$\mathbf{Pr = -36.6 + Pt + Gt + Gr - 20\log(f\ MHz) - 20\log(r)}$$ {r = miles *1609.3m/mile}

$$\mathbf{Pr = -32.5 + Pt + Gt + Gr - 20\log(f\ MHz) - 20\log(r)}$$ {r = km *0.001m/km}

TCAS: TX at 1030 MHz; RX at 1090 MHz.
Maximum ERP = Pt*Gt = TRP(360/BW) = 400W = 56 dBm.

L-Band Satcom: TX at 1626.5 – 1646.5 MHz with 5kHz channel spacing.
RX at 1530.0 – 1545.0 MHz (Inm-C) & 1575.42 MHz (GPS).
ERPmax = 16dBW = 46dBm = 39.8W ~ 40W (~20W with 3dB gain).
VSWR ≤ 1.5:1; Z = 50Ω; polarization = RHCP
G =

IFF: TX at 1090 MHz; RX at 1030 MHz.
Peak pulse power at transponder = 27 ± 3 dBW = 30 dBW max = 1000 W = 60dBm
Gt max = 0 dB (includes line loss)

GPS: L1 = 1575.42 MHz; L2 = 1227.6 MHz
Gr = -1.0 dBic angles between 0 deg & 75 deg from vertical; -7.5dBic @horizon.
Antenna out-of-band rejection is: >6dB@ 1177 MHz, >10dB @ 1277, >20db @ 1525, >25dB @ 1625 MHz. [These are approximately L1 & L2 +/- 50 MHz]
Antenna VSWR <= 2.0 to 1.
Preamp gain = 22-38dB at L1 & L2; filter rejection = 1dB at carrier +/- 15MHz, 3dB at +/- 60MHz, 50db at +/- 100MHz.
Out-of-Band Interference: GPS shall handle 0 dBm continuous RF power applied to preamp without degradation of performance for interference outside L1 & L2 bandwidths of ± 100 MHz and from 50 to 12000 MHz (50Mhz- 12GHz). [50 – 1127.6 and 1327.6 – 1475.42 and 1675.42 – 12000 MHz]
Gp = spread spectrum processing gain = code rate/data rate.
Therefore C/A code Gp = 1MHz/50Hz = 20,000 = 43dB; p-code Gp = 10MHz/50Hz = 200,000 = 53dB.
Burnout Level: At L1 & L2, unit can sustain 10dBm, CW, applied to preamp input for 1minute without damage. Outside L1 & L2 ± 100MHz, unit can sustain 3W(34.77 dBm), CW, applied to preamp input for 1 minute without damage.

<u>Upper IFF vs GPS Analysis:</u> IFF location = FS 513; GPS locations = FS 623 & FS 653.

Separation distance = 623 – 513 = 110 in/12 = 9.17 ft

Pr = 37.82 + Pt + Gt + Gr - 20log(f MHz) - 20log(r) {r = feet *0.3048m/ft}
Pr = 37.82 + 60 dBm + 0 – 7.5 –20log(1090) – 20log(9.17)
= 97.82 – 7.5 – 60.75 – 19.25 = **10.32 dBm**
However antenna out-of-band rejection is >6dB, and polarization mismatch is –3dB.
Therefore, 10.32 – 9 dB = **1.32dBm** which is slightly above the 0dBm requirement for CW interference without performance degradation. However, IFF power is likely to be 500W (3dB less), and antenna rejection is likely to be > 6dB at 1090 MHz.

<u>L-band Satcom vs IFF:</u>