UAT-WP-14
2 April 2001

RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #3

UAT Performance in LA 2020 Traffic Levels with JTIDS Interference and Some DME Compatibility Considerations

Presented by S. R. Jones

SUMMARY
Lots of graphs

Nt(60) = 302   ah = 40000   D1 = 246   Ro = 124 μu = 0   σu = 5.5   Rp = 400   Nt(Rp) = 1199

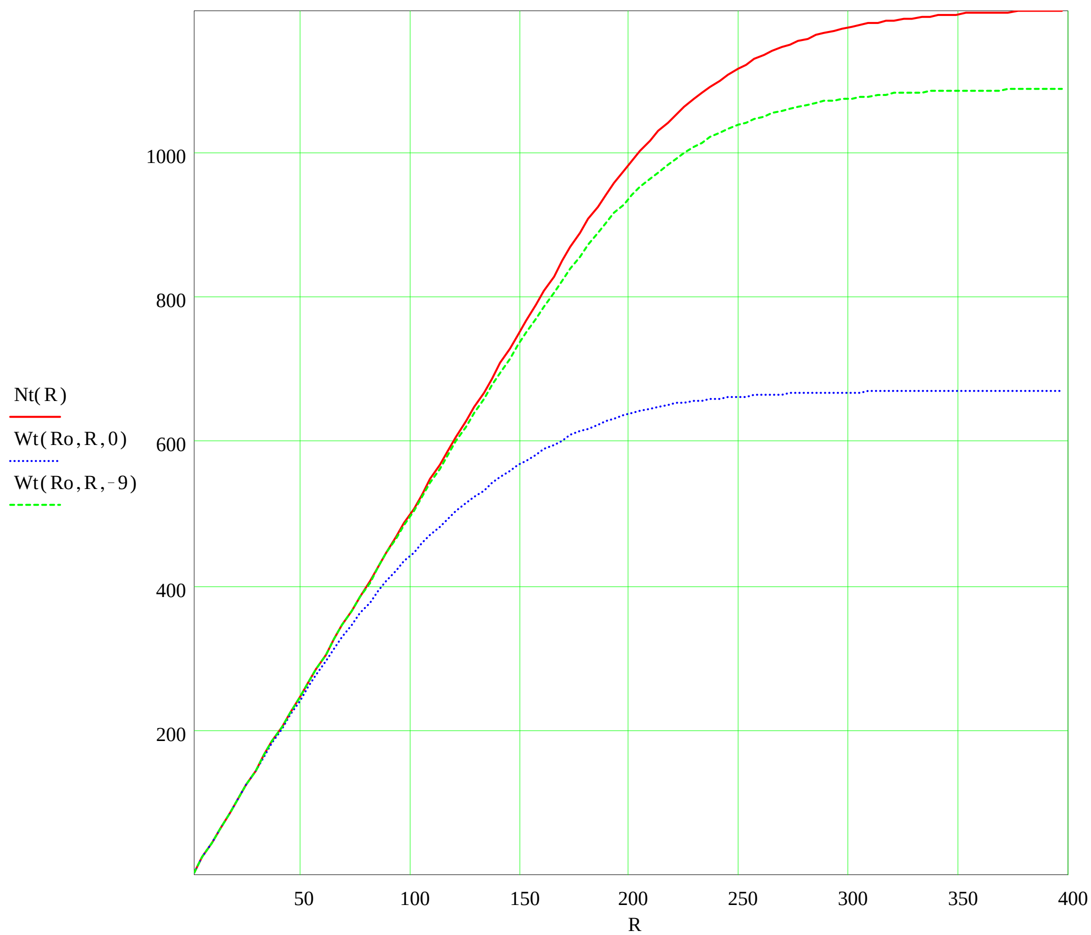


Figure 1 Future traffic distribution vs distance from LAX (nm) for LA 2020 scenario (solid). Number with signal level at least equal to MTL at Ro (dotted). Number with signal level at least equal to MTL- 9 dB (dashed).

PROPOSED POWER LEVELS

Power Classification	Min ERP	Max ERP	Class Avg ERP	Relative to 66 w (48.2 dBm)
Low	5 w (37 dBm)	25 w (44 dBm)	11 w (40.5 dBm)	-7.7 dB
Medium	12.5 w (41 dBm)	62.5 w (48 dBm)	28 w (44.5 dBm)	-3.7 dB
High	100 w (50 dBm)	250 w (54 dBm)	128 w (52 dBm)	+3.8 dB

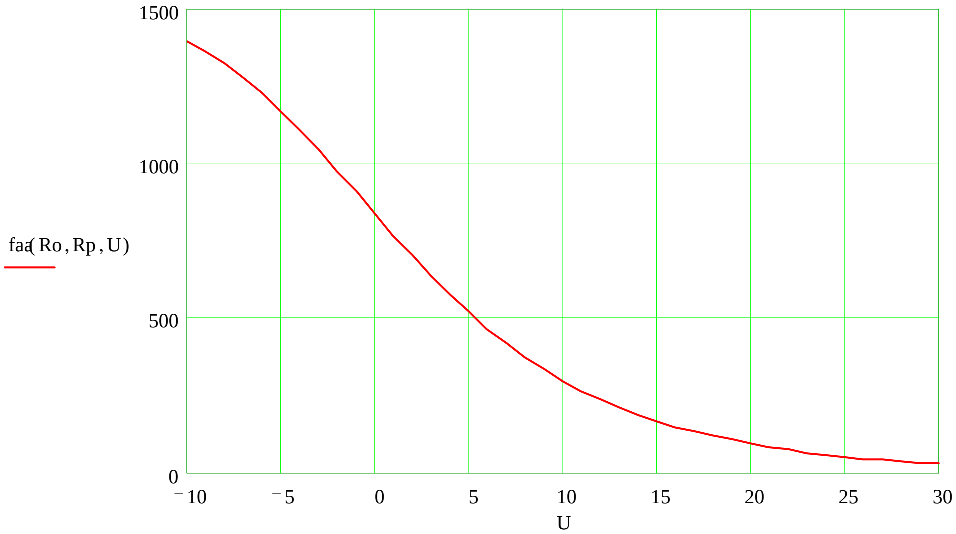


Figure 2(a) UAT self-interference at 40000 ft altitude for proposed power levels (messages/sec): normalized to –91 dBm

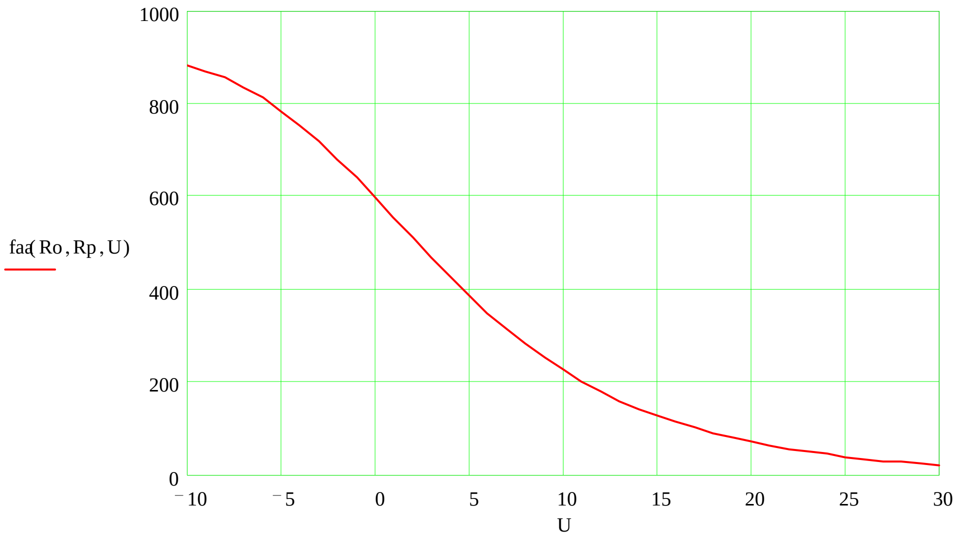
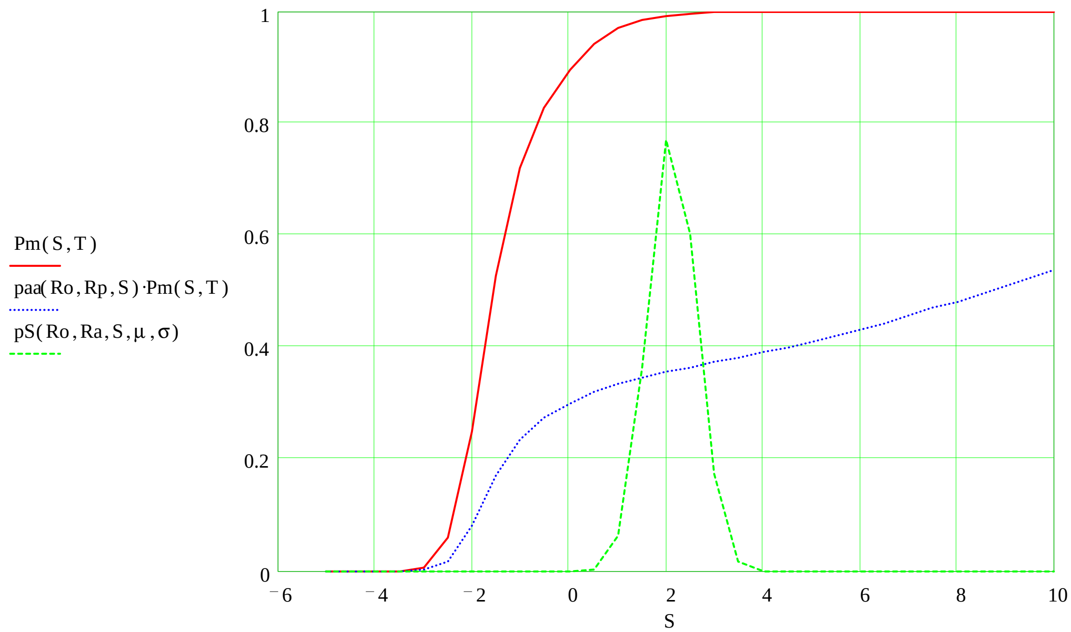


Figure 2(b) UAT self-interference at 15000 ft altitude for proposed power levels (messages/sec): normalized to –91 dBm

Rp = 400 Nt(60) = 302 μu = 0 σu = 5.5 za = 1.25 ah = 40000 Ro = 124

Ra = 40 μ = ⁻7.7 σ = 0.5 Nt(Rp) = 1199



Rp = 400 Nt(60) = 229 μu = 0 σu = 5.5 za = 1.25 ah = 15000 Ro = 124

Ra = 40 μ = ⁻7.7 σ = 0.5 Nt(Rp) = 735

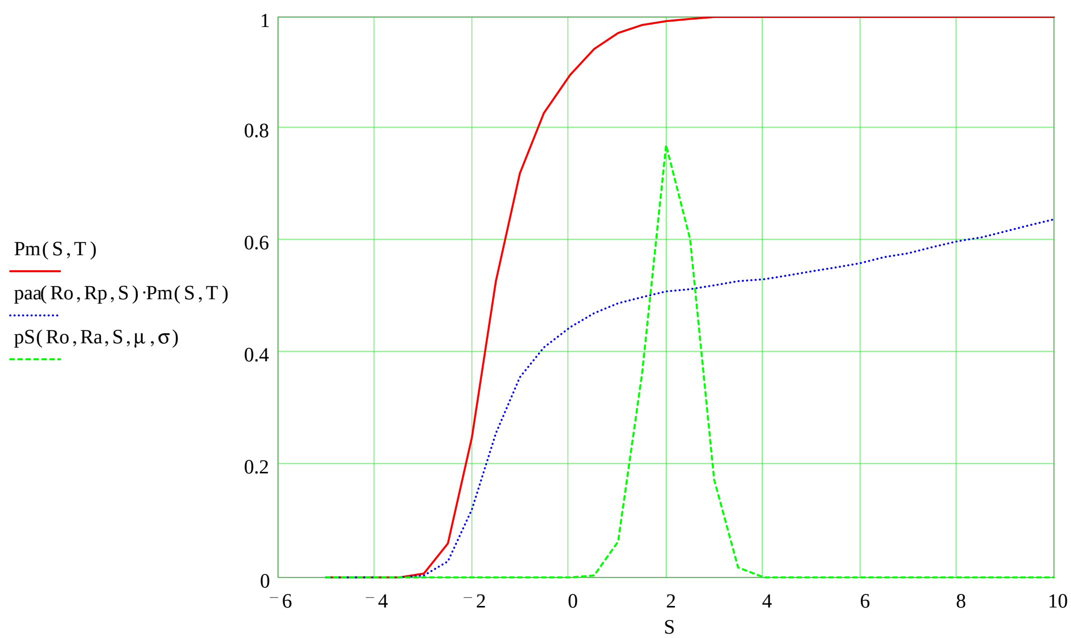
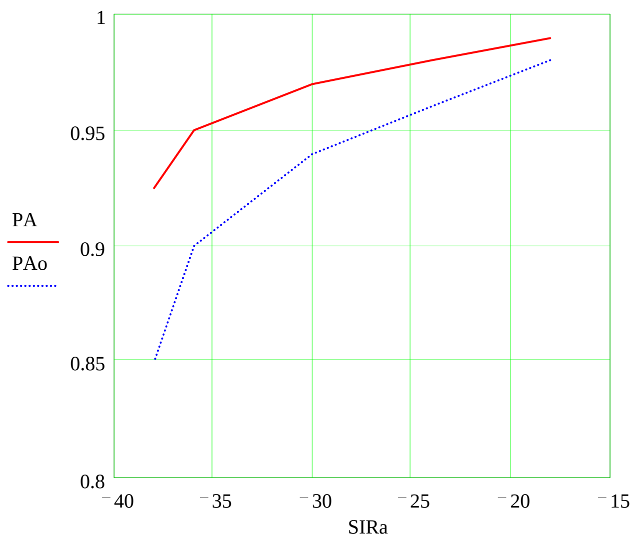


Figure 3 Receiver-decoder model normalized to –91 dBm MTL and 40000 ft interference level (top), and 15000 ft interference level (bottom) with examples of signal pdf at range, Ra

New Leiter-Wilson UAT Waveform:

From Fig 4 & 8 UAT-WP-2-03
for long ADS-B at 981:

$$SIRa := \begin{bmatrix} -18 \\ -24 \\ -30 \\ -36 \\ -38 \end{bmatrix} \quad PAo := \begin{bmatrix} .98 \\ .96 \\ .94 \\ .90 \\ .85 \end{bmatrix} \quad PA := \begin{bmatrix} .99 \\ .98 \\ .97 \\ .95 \\ .925 \end{bmatrix}$$



$$SIRd := 0, -2 .. -40$$

$$PA1(SIRd) := 1 - 1 \cdot \exp(-0.19 \cdot (SIRd + 48)) \qquad Pac(SIRd) := 1 - 0.002 \cdot \exp(-0.09 \cdot SIRd)$$

$$PAc(SIRd) := 1 - 0.5 \cdot \exp(-0.19 \cdot (SIRd + 48))$$

PAc, analytic fit to PA PAc, analytic fit to PA

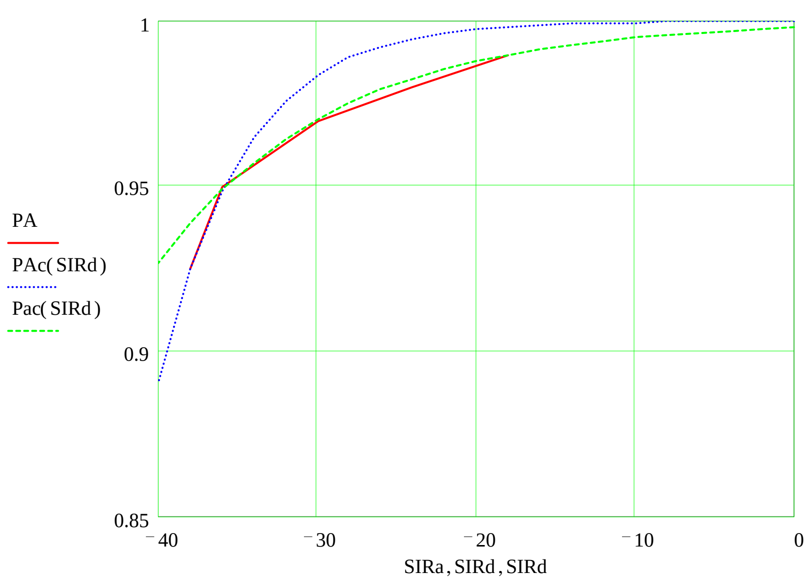


Figure 4 Analytic approximations to JTIDS interference effects on UAT Leiter-Wilson waveform for TSDF = 50%.

For total net/single unit TSDF of 100/50 and air-air UAT:

$Gs := 1 \quad Ps := 11$

$Gn := 1 \quad Pn := 200 \quad Rn := 6 \qquad PAnx(Rn, Ra) := 1 - 0.5 \cdot \exp\left[-0.18 \cdot \left[\left[10 \cdot \log\left[\frac{Ps \cdot Gs}{Pn \cdot Gn} \cdot \left(\frac{Rn}{Ra}\right)^2\right]\right] + 48\right]\right]$

$Gu := 1 \quad Pu := 200 \quad Ru := 3 \qquad PAu(Ru, Ra) := 1 - 0.5 \cdot \exp\left[-0.18 \cdot \left[\left[10 \cdot \log\left[\frac{Ps \cdot Gs}{Pu \cdot Gu} \cdot \left(\frac{Ru}{Ra}\right)^2\right]\right] + 48\right]\right]$

$PJ(Ru, Rn, Ra) := 1 - (1 - PAu(Ru, Ra)) - (1 - PAnx(Rn, Ra))$

$Paj(Ro, Ra, S, \mu, \sigma, Ru, Rn) := (Prr(Ro, Ra, S, \mu, \sigma)) \cdot PJ(Ru, Rn, Ra)$

$PJ(Ru, Rn, 10) = 0.992 \quad Prr(Ro, 10, -3, \mu, \sigma) = 0.601 \qquad Paj(Ro, 10, -3, \mu, \sigma, Ru, Rn) = 0.597$

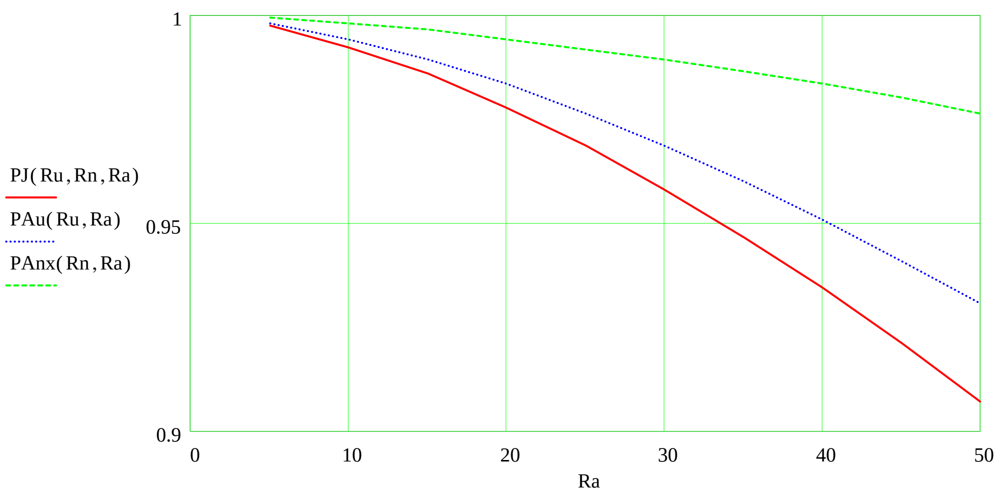
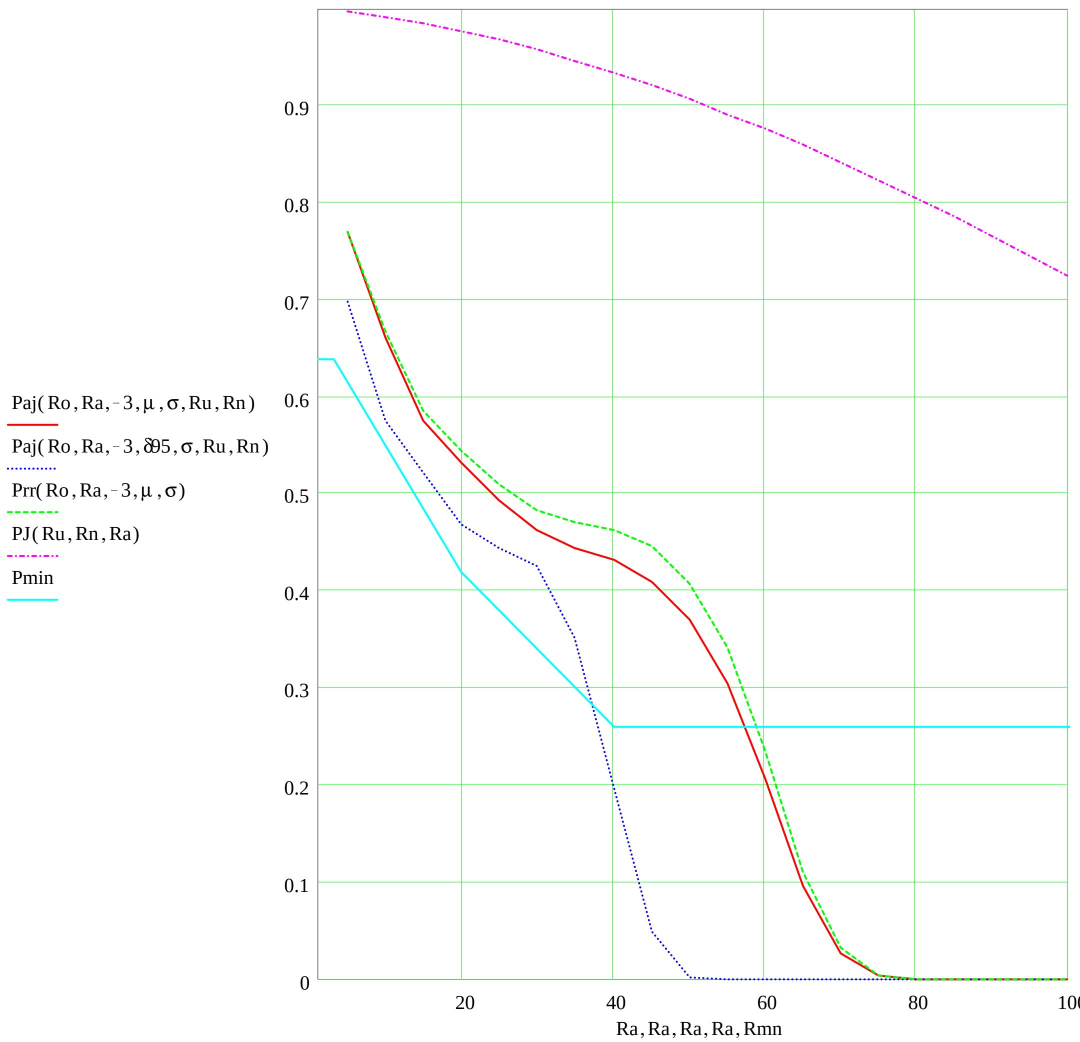


Figure 5 Example of JTIDS effect on low power UAT for assumed threat scenario

$Nt(400) = 735$ $\mu u = 0$ $\sigma u = 5.5$ $faa(Ro, Rp, 0) = 600$ $ah = 15000$ $Ro = 124$ $D1 = 151$

$\sigma c = 2.2$ $\mu = -7.7$ $\sigma = 0.5$ $\eta = 0.9$ $\gamma u = 9$ $MTL - T = 2$ $Pm(0, T) = 0.9$

$Ru = 3$ $Rn = 6$ $Gs = 1$ $Ps = 11$ $Gu = 1$ $Pu = 200$ $Gn = 1$ $Pn = 200$



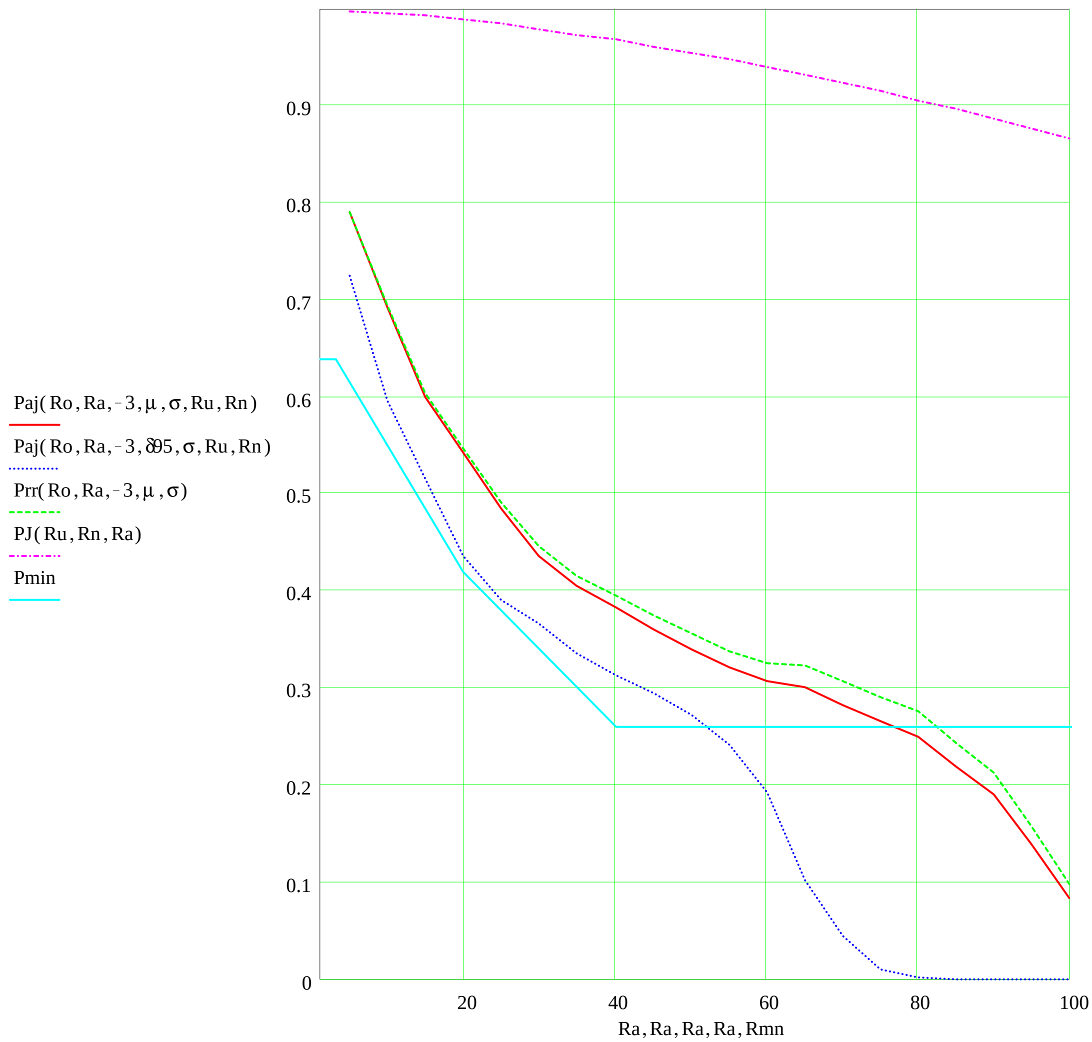
Probability of UAT message decode as a function of separation range for 50% of the user equipage class population (dashed) and JTIDS effect on UAT message decode for conditions shown (dash-dot), and joint results (solid). Joint results for 95% of class (dotted)

Figure 6 Aggregate LA 2020 with JTIDS results for proposed low power equipage class (ERP = 11 w) and 10% loss due to co-site and DME interference (ACR = 40 dB). Altitude = 15000 feet.

$Nt(400) = 1199$ $\mu u = 0$ $\sigma u = 5.5$ $faa(Ro, Rp, 0) = 840$ $ah = 40000$ $Ro = 124$ $D1 = 246$

$\sigma c = 2.2$ $\mu = -3.7$ $\sigma = 0.5$ $\eta = 0.9$ $\gamma u = 9$ $MTL - T = 2$ $Pm(0, T) = 0.9$

$Ru = 3$ $Rn = 6$ $Gs = 1$ $Ps = 28$ $Gu = 1$ $Pu = 200$ $Gn = 1$ $Pn = 200$



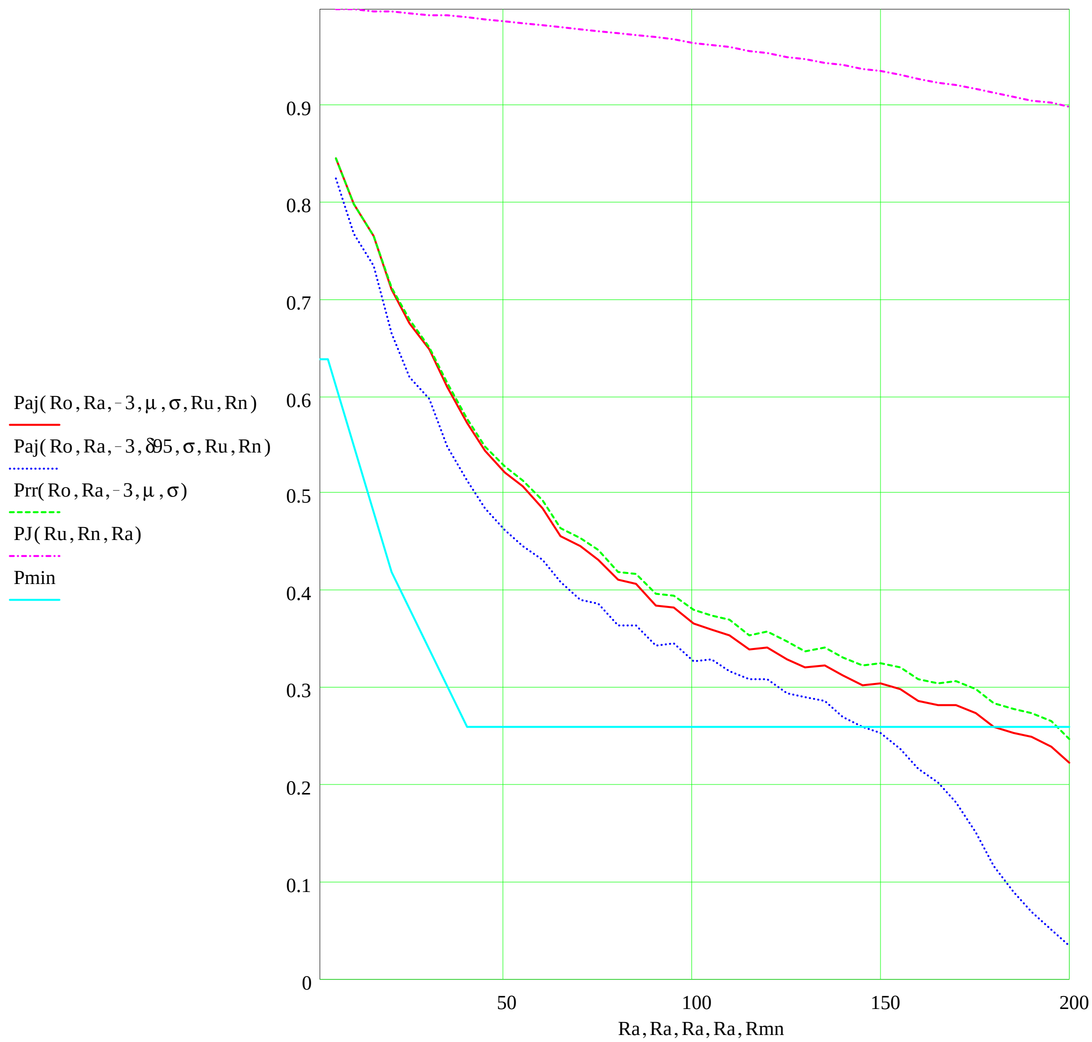
Probability of UAT message decode as a function of separation range for 50% of the user equipage class population (dashed) and JTIDS effect on UAT message decode for conditions shown (dash-dot), and joint results (solid). Joint results for 95% of class (dotted)

Figure 7 Aggregate LA 2020 with JTIDS results for proposed medium power equipage class (ERP = 28 w) and 10% loss due to co-site and DME interference (ACR = 40 dB). Altitude = 40000 feet.

Nt(400) = 1199   μu = 0   σu = 5.5   faa(Ro, Rp, 0) = 840   ah = 40000   Ro = 124   D1 = 246

σc = 1.3   μ = 3.8   σ = 0.5   η = 0.9   γu = 9   MTL − T = 2   Pm(0, T) = 0.9

Ru = 3   Rn = 6   Gs = 1   Ps = 158   Gu = 1   Pu = 200   Gn = 1   Pn = 200



Probability of UAT message decode as a function of separation range for 50% of the user equipage class population (dashed) and JTIDS effect on UAT message decode for conditions shown (dash-dot), and joint results (solid). Joint results for 95% of class (dotted)

Figure 8 Aggregate LA 2020 with JTIDS results for proposed high power equipage class (ERP = 158 w) and 10% loss due to co-site and DME interference (ACR = 40 dB). Altitude = 40000 feet.

REVISED POWER LEVELS

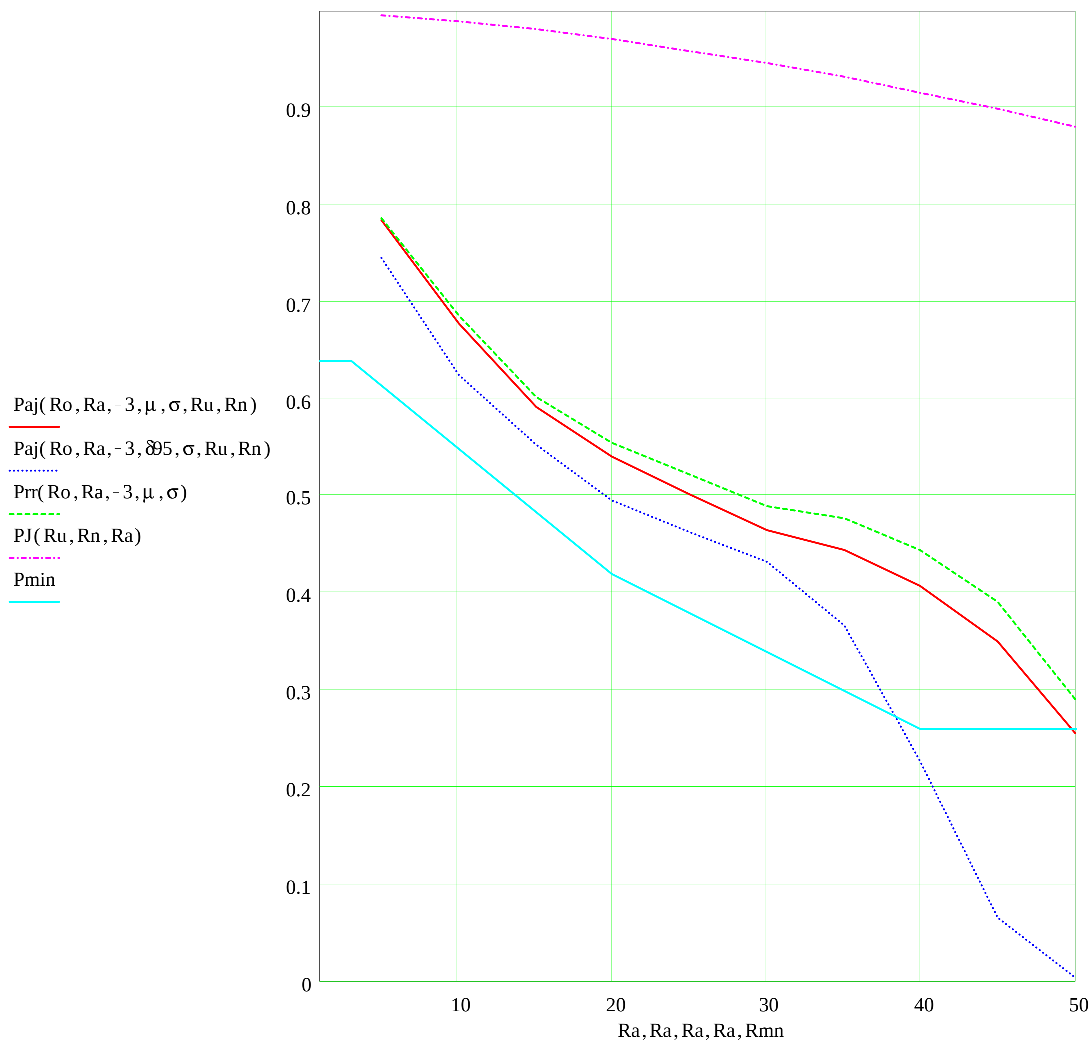
Power Classification	Min ERP	Max ERP	Class Avg ERP	Relative to 41 w (46 dBm)
Low	5 w (37 dBm)	12.5 w (41 dBm)	8 w (39 dBm)	-7 dB
Medium	12.5 w (41 dBm)	31.2 w (45 dBm)	20 w (43 dBm)	-3 dB
High	60 w (47.8 dBm)	150 w (51.8 dBm)	95 w (49.8 dBm)	+3.8 dB

Reduces maximum power by 2 dB and maintains 4 dB power variation in each class.

$Nt(400) = 735$ $\mu u = 0$ $\sigma u = 5$ $faa(Ro, Rp, 0) = 509$ $ah = 15000$ $Ro = 98$ $D1 = 151$

$\sigma c = 1.3$ $\mu = -7$ $\sigma = 0.5$ $\eta = 0.9$ $\gamma u = 9$ $MTL - T = 2$ $Pm(0, T) = 0.9$

$Ru = 3$ $Rn = 6$ $Gs = 1$ $Ps = 8$ $Gu = 1$ $Pu = 200$ $Gn = 1$ $Pn = 200$



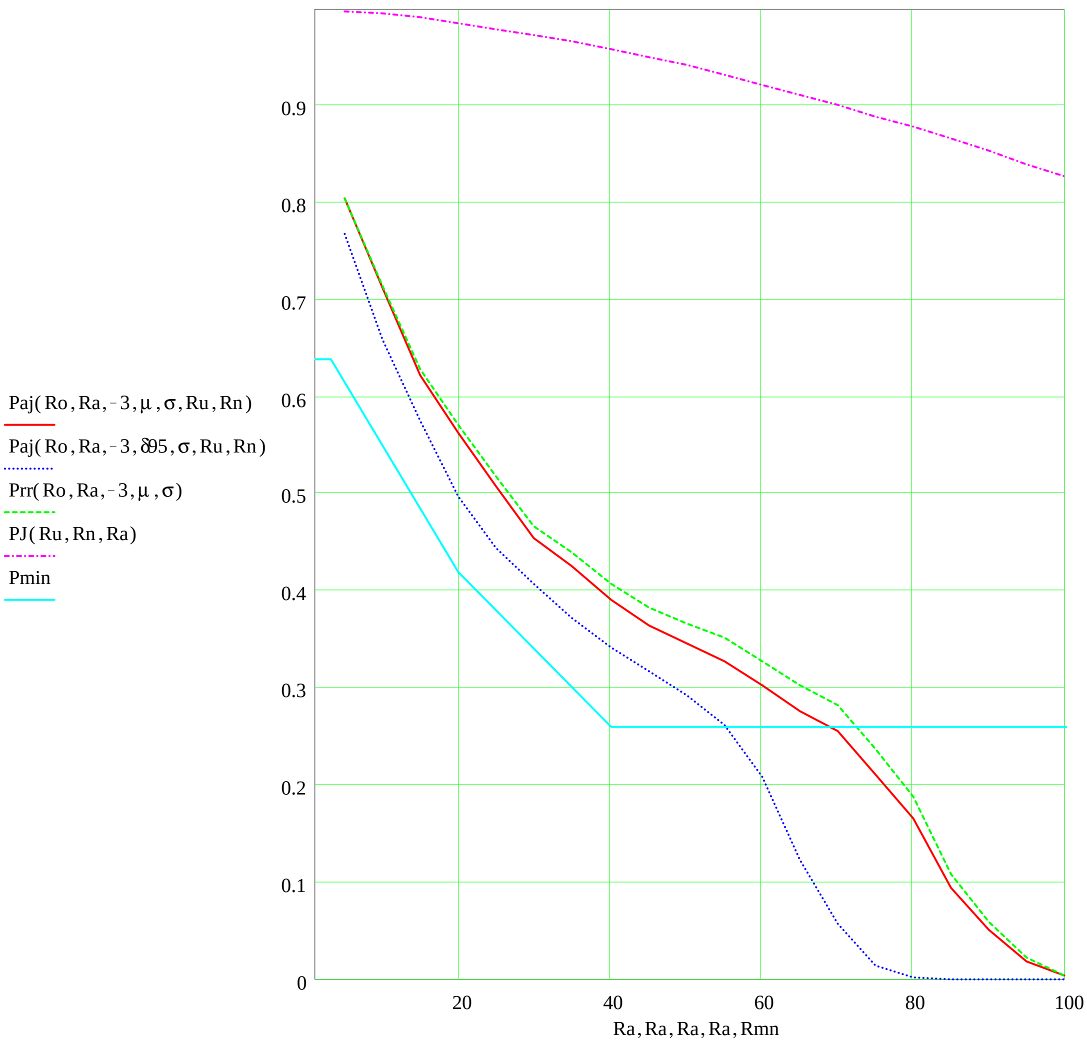
Probability of UAT message decode as a function of separation range for 50% of the user equipage class population (dashed) and JTIDS effect on UAT message decode for conditions shown (dash-dot), and joint results (solid). Joint results for 95% of class (dotted)

Figure 9 Aggregate LA 2020 with JTIDS results for revised low power equipage class (ERP = 8 w) and 10% loss due to co-site and DME interference (ACR = 40 dB). Altitude = 15000 feet.

$Nt(400) = 1199$ $\mu u = 0$ $\sigma u = 5$ $faa(Ro, Rp, 0) = 692$ $ah = 40000$ $Ro = 98$ $D1 = 246$

$\sigma c = 1.3$ $\mu = -3$ $\sigma = 0.5$ $\eta = 0.9$ $\gamma u = 9$ $MTL - T = 2$ $Pm(0, T) = 0.9$

$Ru = 3$ $Rn = 6$ $Gs = 1$ $Ps = 20$ $Gu = 1$ $Pu = 200$ $Gn = 1$ $Pn = 200$



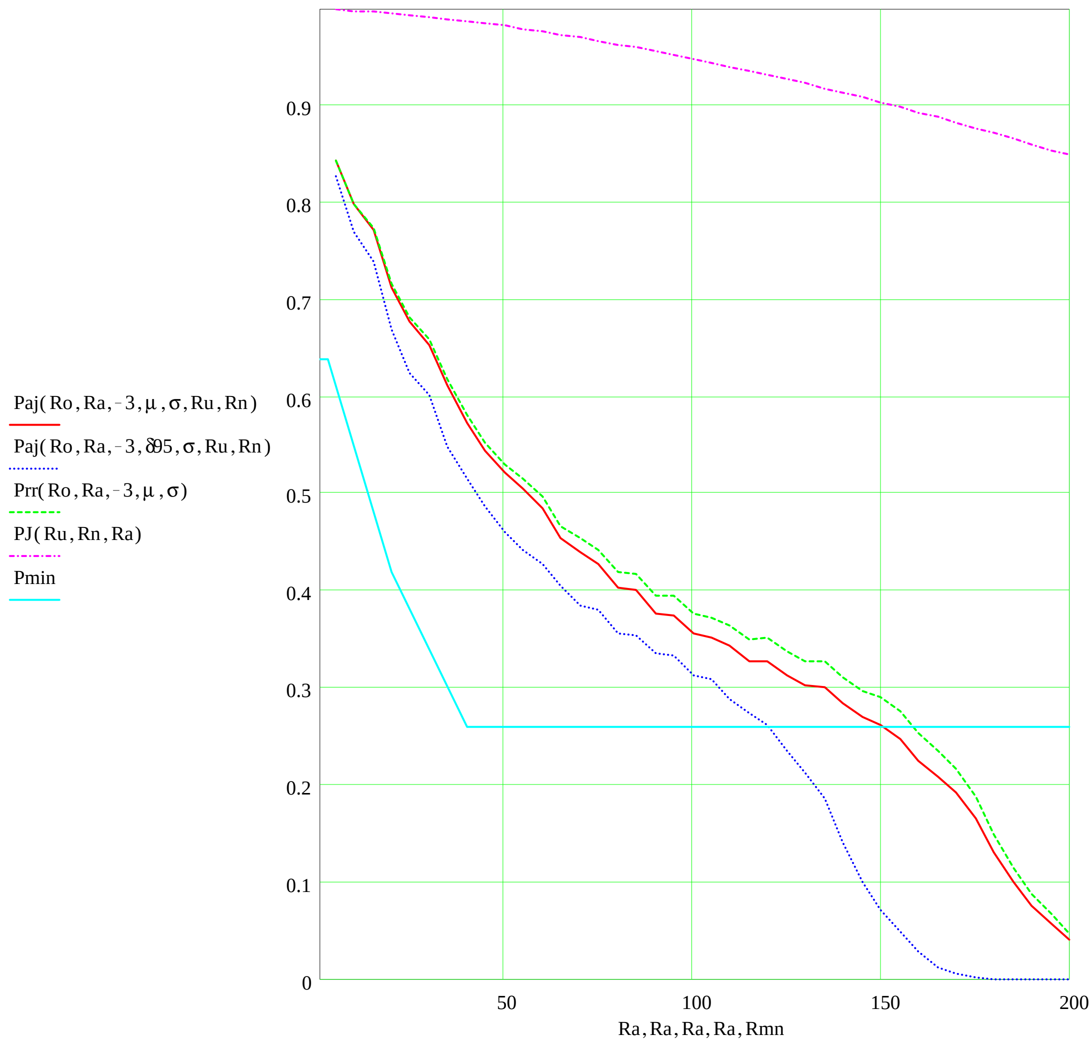
Probability of UAT message decode as a function of separation range for 50% of the user equipage class population (dashed) and JTIDS effect on UAT message decode for conditions shown (dash-dot), and joint results (solid). Joint results for 95% of class (dotted)

Figure 10 Aggregate LA 2020 with JTIDS results for revised medium power equipage class (ERP = 20 w) and 10% loss due to co-site and DME interference (ACR = 40 dB). Altitude = 40000 feet.

$Nt(400) = 1199$ $\mu u = 0$ $\sigma u = 5$ $faa(Ro, Rp, 0) = 692$ $ah = 40000$ $Ro = 98$ $D1 = 246$

$\sigma c = 1.3$ $\mu = 3.8$ $\sigma = 0.5$ $\eta = 0.9$ $\gamma u = 9$ $MTL - T = 2$ $Pm(0, T) = 0.9$

$Ru = 3$ $Rn = 6$ $Gs = 1$ $Ps = 95$ $Gu = 1$ $Pu = 200$ $Gn = 1$ $Pn = 200$



Probability of UAT message decode as a function of separation range for 50% of the user equipage class population (dashed) and JTIDS effect on UAT message decode for conditions shown (dash-dot), and joint results (solid). Joint results for 95% of class (dotted)

Figure 11 Aggregate LA 2020 with JTIDS results for revised high power equipage class (ERP = 95 w) and 10% loss due to co-site and DME interference (ACR = 40 dB). Altitude = 40000 feet.

$Nt(60) = 101$ $ah = 40000$ $D1 = 246$ $Ro = 98$ $\mu u = 0$ $\sigma u = 5$ $Rp = 400$ $Nt(Rp) = 400$

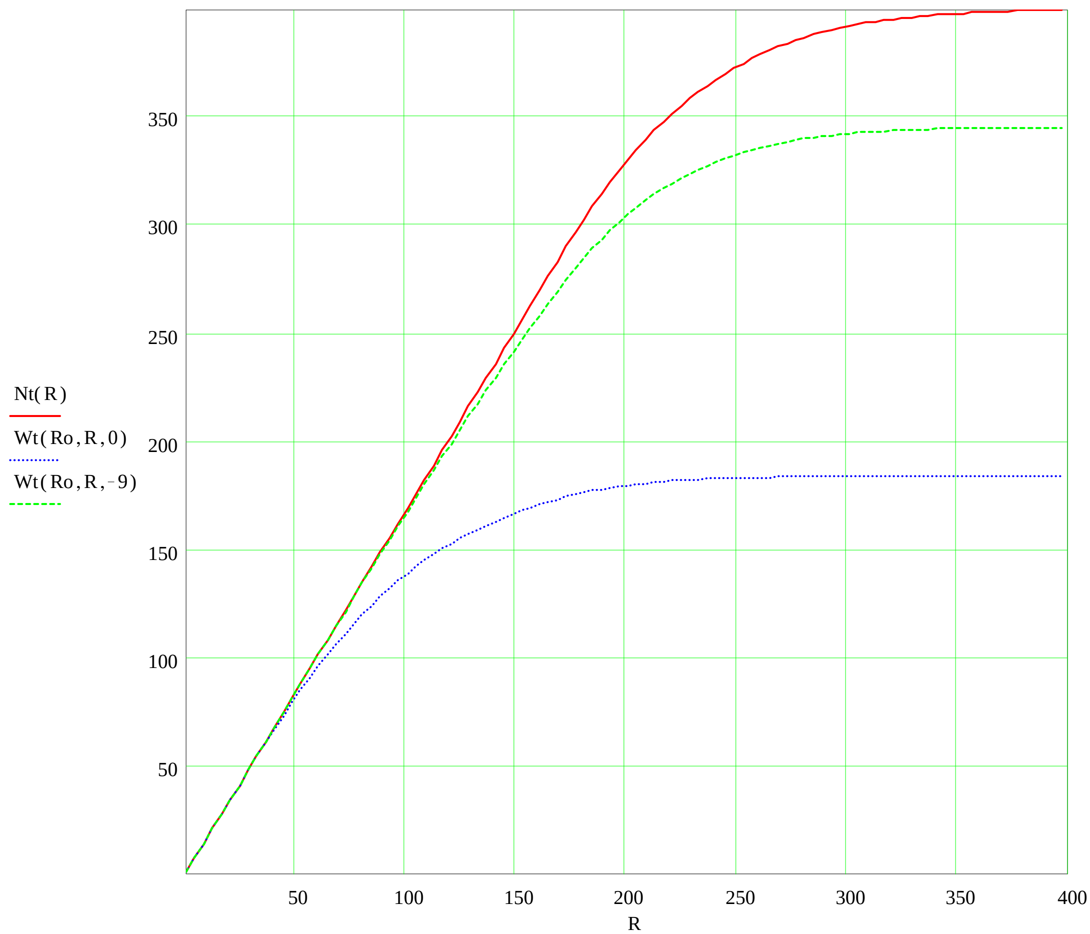


Figure 12 Low density traffic distribution

$Pdc(Rs) := \exp(-0.0065 Rs)$

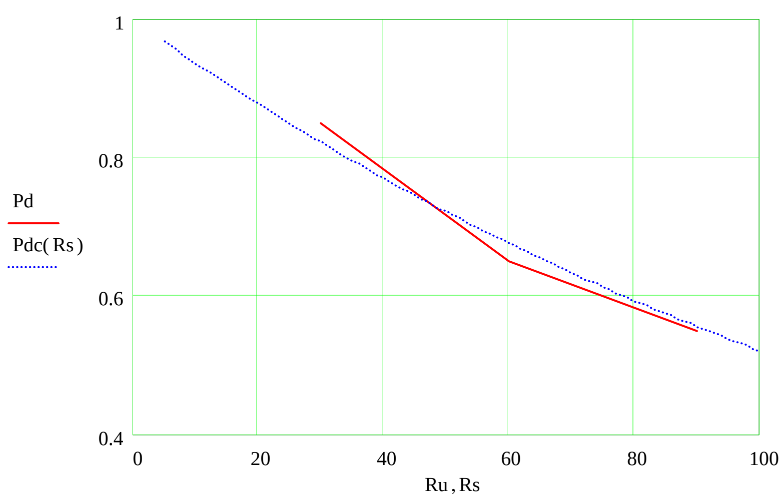
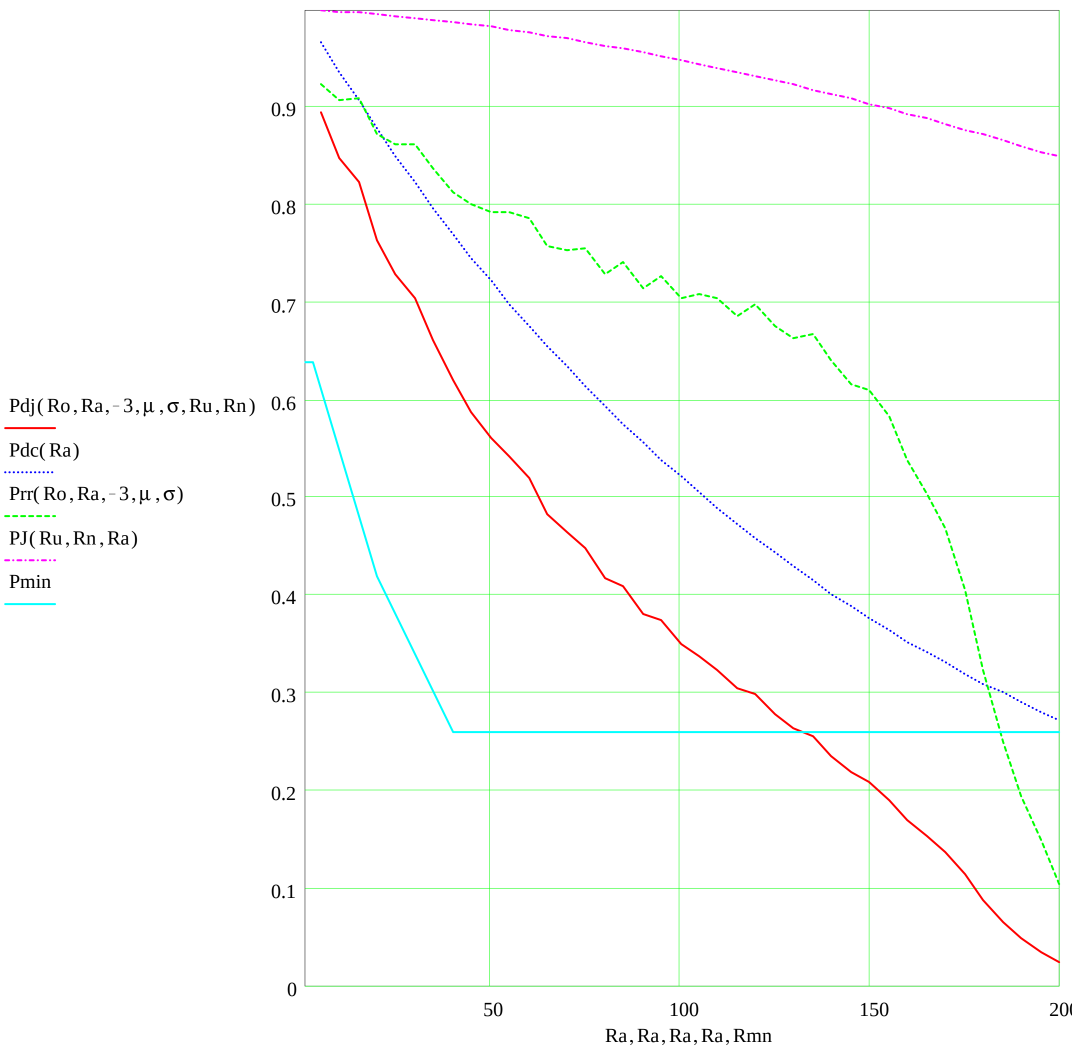


Figure 13 On-channel plus Adjacent channel DME interference with ACR = 20 dB based on Leiter-Wilson

Nt(400) = 400 μu = 0 σu = 5 faa(Ro, Rp, 0) = 231 ah = 40000 Ro = 98 D1 = 246

σc = 1.3 μ = 3.8 σ = 0.5 η = 0.95 γu = 9 MTL – T = 2 Pm(0, T) = 0.9

Ru = 3 Rn = 6 Gs = 1 Ps = 95 Gu = 1 Pu = 200 Gn = 1 Pn = 200

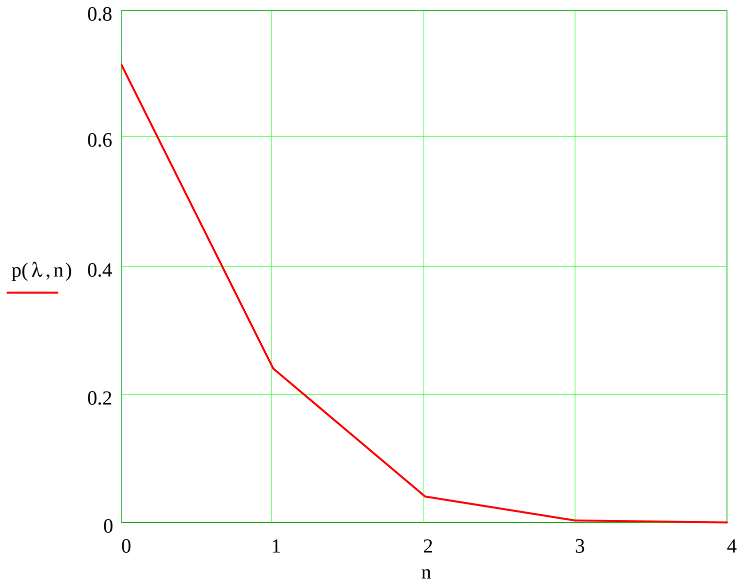


Probability of UAT message decode as a function of separation range for 50% of the user equipage class population (dashed) and JTIDS effect on UAT message decode for conditions shown (dash-dot), DME withACR = 20 dB (dotted), and joint results (solid).

Figure 14 UAT performance (high power class) with JTIDS and on-channel plus adjacent channel DME interference when near on-channel DME with ACR = 20 dB

Probability exactly n arrivals in T sec $T := (400 + 20)\cdot 10^{-6}$ $\nu := 800$

$\lambda := T\cdot\nu$ $\lambda = 0.336$ $p(\lambda, n) := e^{-\lambda}\cdot\frac{\lambda^{n}}{n!}$ $n := 0, 1 .. 4$



$T = 4.2\cdot 10^{-4}$

$\nu = 800$

Probability interarrival time is at least t $C(\nu, t) := \exp(-\nu\cdot t)$ $t := T$ $t = 4.2\cdot 10^{-4}$

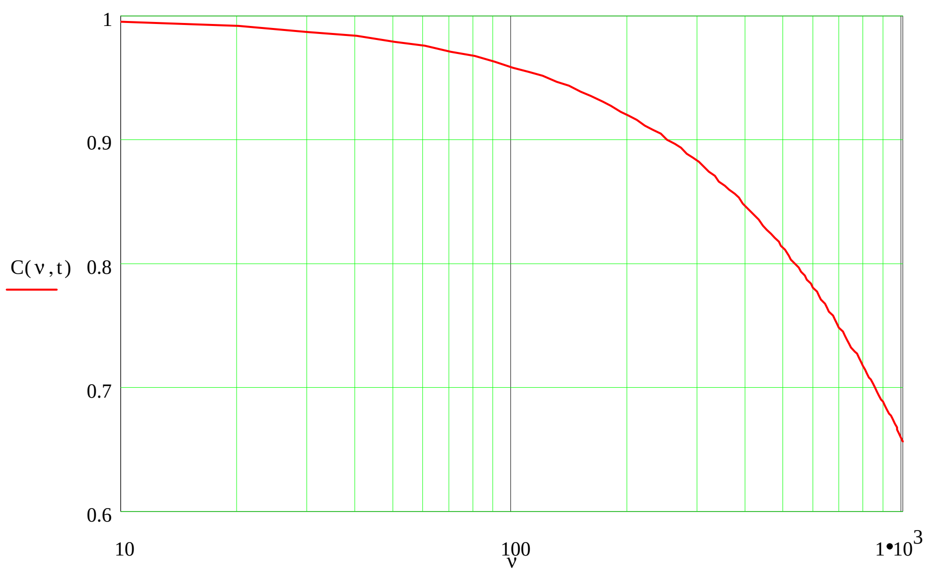


Figure 15 UAT interference potential on DME