APPENDIX A: HARDWARE SPECIFICATION

A.1 RF Components

A1 - Fixed Coaxial Attenuator
- Manufacturer: Midwest Microwave
- Model: ATT-0444-03-SMA-02
- Frequency range: 0 - 18 GHz
- Attenuation: 3 dB

A2 - Fixed Coaxial Attenuator (3x)
- Manufacturer: Midwest Microwave
- Model: ATT-0444-10-SMA-02
- Frequency range: 0 - 18 GHz
- Attenuation: 10 dB

B - DC Blocking Capacitor
- Manufacturer: Picosecond Pulse Labs
- Model: 5502C
- BW(-3dB): 14 GHz
- Rise time: 24 ps
- Delay: 154 ps
- Insertion loss: < 0.5 dB @ 2 GHz

C - 3 way (0 degree) Power Combiner
- Manufacturer: Midwest Microwave
- Model: PWD-5520-03-SMA-79
- Frequency range: 0.5 - 2.0 GHz
- Isolation: 15-dB minimum
- Amplitude balanced: 0.5 dB
- Phase balanced: 5 degrees
- Insertion loss: 5 dB @ 1575 MHz

DC - Directional Coupler
- Manufacturer: Mini-Circuits
- Model: ZFDC-10-5
- Frequency range: 1 - 2000 MHz
- Coupling: 10.8 dB
- Main line loss: 1.8-dB max
- Directivity: 30 dB

F3 - Band Pass Filter

Manufacturer: TTE
Type: 315-1575.42M-24M-50-SMA
Center frequency (f_0): 1575.42 MHz
Passband bandwidth: 0.015 f_0, minimum
Insertion loss at f_0: < -2 dB

F5 - Band Pass Filter

Manufacturer: TTE
Type: 305-1575.42M-50M-50-SMA
Center frequency (f_0): 1575.42 MHz
Passband bandwidth: 0.043 f_0
Insertion loss at f_0: < -0.3 dB

G1 - Medium Power Amplifier

Manufacturer: Mini-Circuits
Model: ZFL-2000
Frequency range: 10 - 2000 MHz
Gain at 1575.42MHz : 27 dB
Noise figure: 7 dB
Maximum power: +16dBm

G2 - Low Noise Amplifier

Manufacturer: Mini-Circuits
Model: ZHL-1217HLN
Frequency range: 1200 - 1700 MHz
Gain at 1575.42MHz : 39 dB (measured)
Noise figure: 1.5 dB
Maximum power: +26 dBm

ND2 - Noise Diode

Manufacturer: Noise / Com, Inc
Model: NC3108A
Serial No. E574
ENR: 27.02 dB @ 1.0 GHz
ENR: 26.65 dB @ 2.0 GHz

S - 4 way, 0 deg Power Splitter

Manufacturer: Mini-Circuits
Model: ZA4PD-2
Frequency range: 1 - 2 GHz
Isolation: 25 dB
Insertion loss: 6 dB

SW - Coaxial Switch
Manufacturer: Dow-Key Microwave
Model: 401-2308
RF circuit: SPDT
Frequency range: 0 - 26.5 GHz

T - Termination, SMA, 50 Ohm, 1 Watt
Manufacturer: Inmet
Model: TS180M
Frequency range: 0 - 18 GHz

VA1 - Step Attenuator (Programmable)
Manufacturer: Hewlett Packard
Model: HP8495G
Frequency range: 0 - 4 GHz
Attenuation range: 0 - 70 dB, 10-dB step

VA2 - Step Attenuator (Programmable)
Manufacturer: Hewlett Packard
Model: HP8494H
Frequency range: 0 - 18 GHz
Attenuation range: 0 - 11 dB, 1-dB step

VA3 - Step Attenuator (Programmable)
Manufacturer: Hewlett Packard
Model: HP8496G
Frequency range: 0 - 4 GHz
Attenuation range: 0 - 110 dB, 10-dB step

VA4 - Step Attenuator (Programmable)
Manufacturer: Hewlett Packard
Model: HP8494G
Frequency range: 0 - 4 GHz
Attenuation range: 0 - 11 dB, 1-dB step

VA5 - Step Attenuator (Manual)
Manufacturer: Hewlett Packard
Model: HP8494B
Frequency range: 0 - 18 GHz
Attenuation range: 0 - 11 dB, 1-dB step

VA6 - Step Attenuator (Manual)

Manufacturer: Hewlett Packard
Model: HP8496B
Frequency range: 0 - 18 GHz
Attenuation range: 0 - 110 dB, 10-dB step

VA7 - Step Attenuator (Manual)
Manufacturer: Midwest Microwave
Model: 1044
Frequency range: 0 - 12 GHz
Attenuation range: 0 - 60 dB, 10-dB step and 0 - 10 dB, 1-dB step

A.2 Arbitrary Waveform Generator and Pulse Generator

AWG - Arbitrary Waveform Generator
Manufacturer: Sony / Tektronix
Model: AWG520
Rise time (10 - 90%): ≤ 2.5 ns (amplitude > 1.0 V)
≤ 1.5 ns (amplitude ≤ 1.0 V)
Fall time (10 - 90%): ≤ 2.5 ns (amplitude > 1.0 V)
≤ 1.7 ns (amplitude ≤ 1.0 V)
Bandwidth: 500 MHz
Phase noise: ≤ -90 dBc/Hz (10-kHz offset)
Pulse width: 10-ns minimum

PG1 - UWB Pulse Generators
Manufacturer: Time Domain
Model: Pulser PG-2000
Unit serial number: NTIA-004
Impulse amplitude (50-Ω load): 5.8V
Impulse rise time (10 - 90%): 200 ps
Impulse fall time (90 - 10%): 416 ps
Impulse width (50%): 521 ps
Max. trigger rate: 40 Mpps

A.3 GPS Receivers

Rx 3 - Dynamics (sets carrier tracking bandwidth) = air
Carrier smoothing = 2s
External clock = disabled
Elevation mask = 0°
Clock adjust (clock drift model) = disabled

Position averaging = disabled
GPS channel configuration = L1/L2
Differential GPS protocol = disabled

Rx 4 - Settings fixed and compliant with TSO-C129a aviation receiver specifications.

APPENDIX B: GPS PERFORMANCE MEASUREMENT RESULTS

Each figure in this appendix illustrates a comprehensive summary of measured GPS performance degradation for a given receiver exposed to a UWB signal permutation. Not all scenarios were measured, as summarized in Table B.1.

Table B.1. Single-Source UWB Interference Measurement Figure List

Interference	Rx 3		Rx 4	
Spacing / PRF (MHz) / DC (%)	BL	RQT	BL	RQT
Gaussian noise	B.1.1	3.6 (Section 3)	B.2.1	B.2.1
UPS / 20 / 100, 20	B.1.2, 3	N/A	B.2.2, 3	N/A
UPS / 5 / 100, 20	B.1.4, 5	N/A	B.2.4, 5	N/A
UPS / 1 / 100, 20	B.1.6, 7	N/A	B.2.6, 7	N/A
UPS / 0.1 / 100, 20	B.1.8, 9	N/A	B.2.8, 9	B.2.8, 9
OOK / 20 / 100, 20	B.1.10, 11	N/A	B.2.10, 11	N/A
OOK / 5 / 100, 20	B.1.12, 13	N/A	B.2.12, 13	N/A
OOK / 1 / 100, 20	B.1.14, 15	N/A	B.2.14, 15	N/A
OOK / 0.1 / 100, 20	B.1.16, 17	N/A	B.2.16, 17	B.2.16, 17
50% ARD / 20 / 100, 20	B.1.18, 19	N/A	B.2.18, 19	B.2.18, 19
50% ARD / 5 / 100, 20	B.1.20, 21	N/A	B.2.20, 21	B.2.20, 21
50% ARD / 1 / 100, 20	B.1.22, 23	N/A	B.2.22, 23	B.2.22, 23
50% ARD / 0.1 / 100, 20	B.1.24, 25	N/A	B.2.24, 25	B.2.24, 25
2% RRD / 20 / 100, 20	B.1.26, 27	N/A	B.2.26, 27	B.2.26, 27
2% RRD / 5 / 100, 20	B.1.28, 29	N/A	B.2.28, 29	B.2.28, 29
2% RRD / 1 / 100, 20	B.1.30, 31	N/A	B.2.30, 31	B.2.30, 31
2% RRD / 0.1 / 100, 20	B.1.32, 33	N/A	B.2.32, 33	B.2.32, 33

B.1. Narrow Correlator Receiver (Rx 3) Results

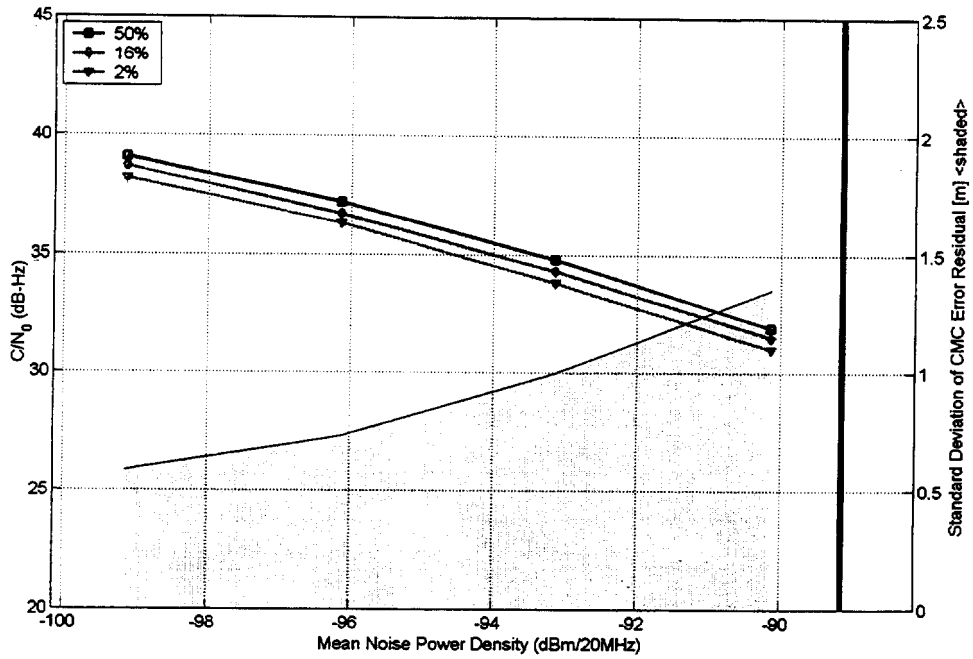

Figure B.1.1. Measured GPS parameters (Rx 3) as a function of Gaussian-noise interference.

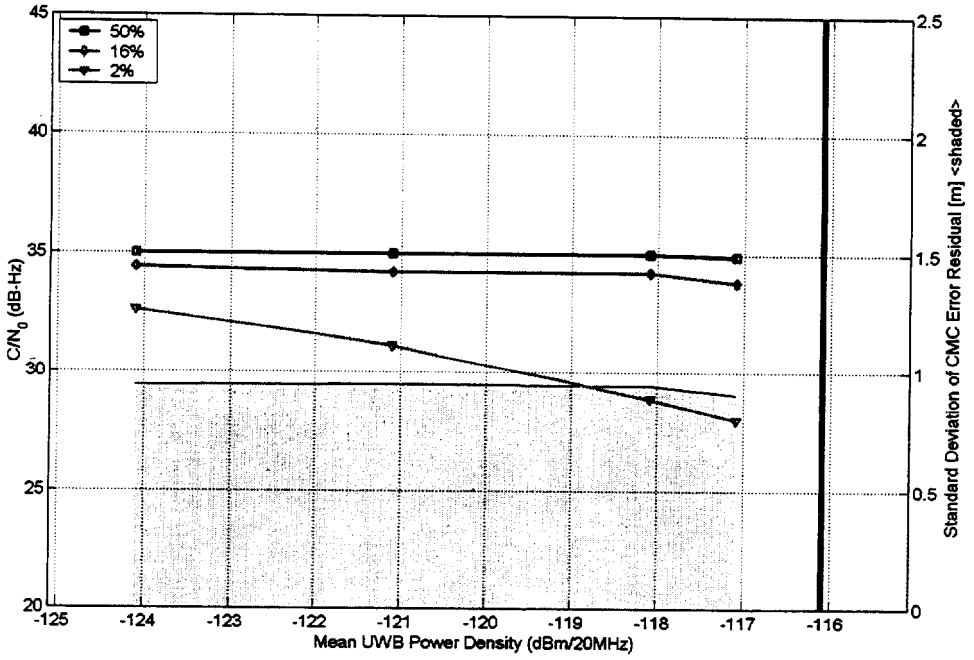

Figure B.1.2. Measured GPS parameters (Rx 3) as a function of 20-MHz PRF, UPS, non-gated UWB interference.

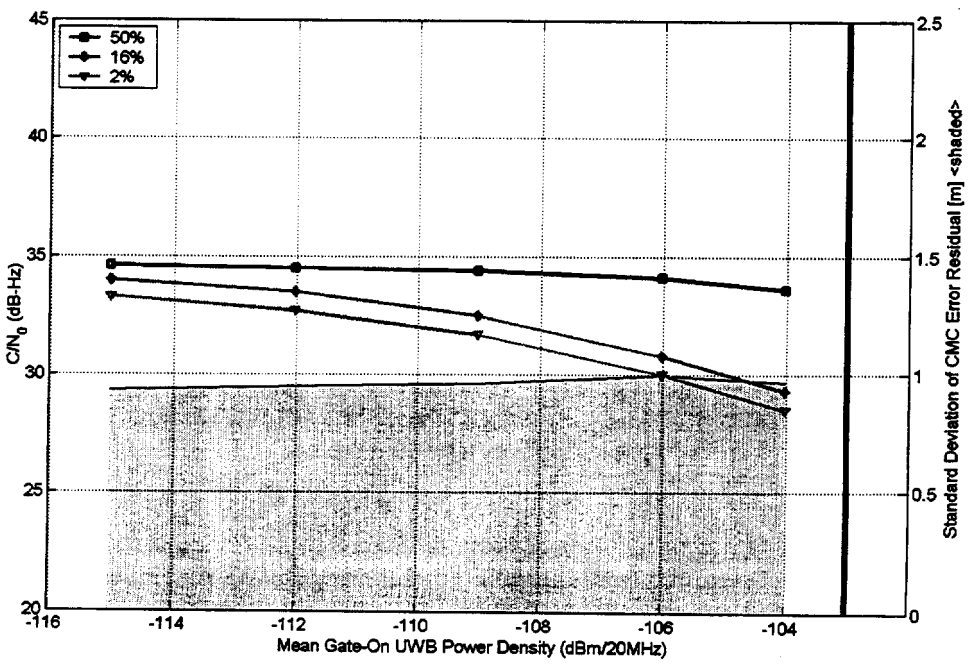

Figure B.1.3. Measured GPS parameters (Rx 3) as a function of 20-MHz PRF, UPS, gated (20% duty cycle) UWB interference.

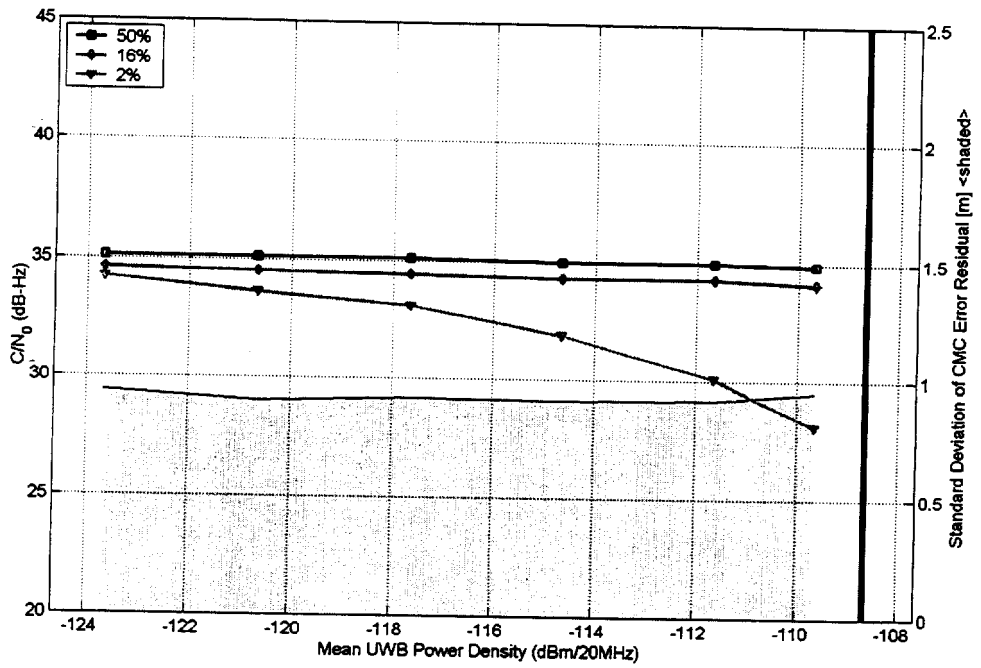

Figure B.1.4. Measured GPS parameters (Rx 3) as a function of 5-MHz PRF, UPS, non-gated UWB interference.

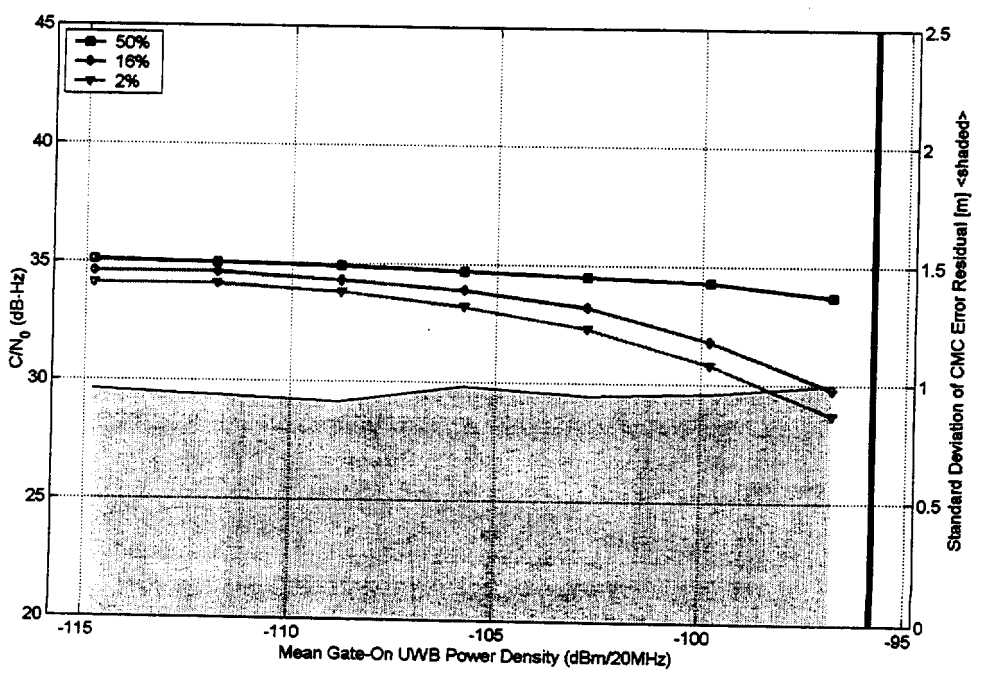

Figure B.1.5. Measured GPS parameters (Rx 3) as a function of 5-MHz PRF, UPS, gated (20% duty cycle) UWB interference.

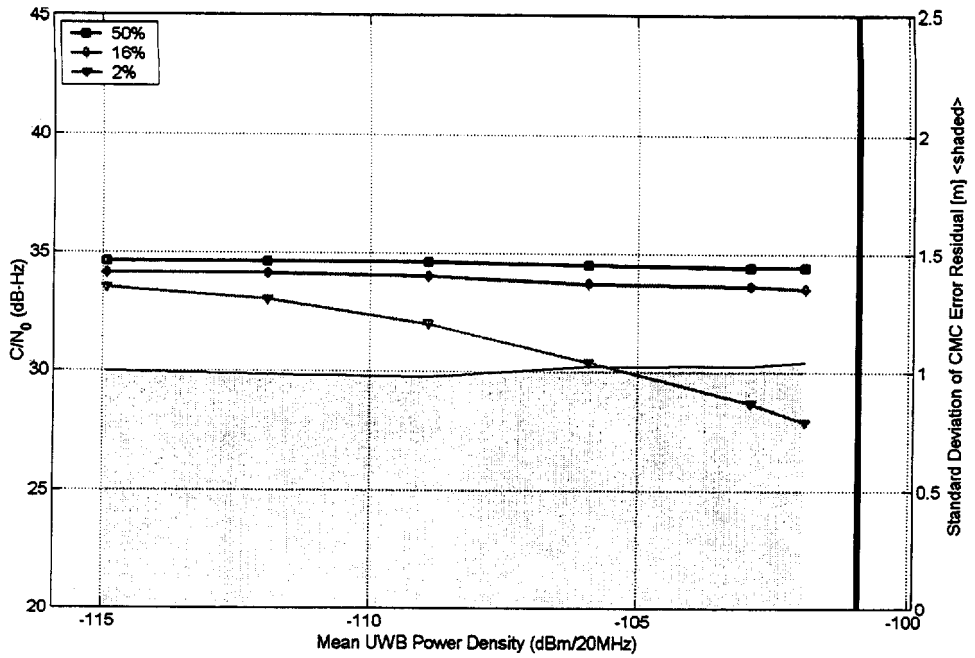

Figure B.1.6. Measured GPS parameters (Rx 3) as a function of 1-MHz PRF, UPS, non-gated UWB interference.

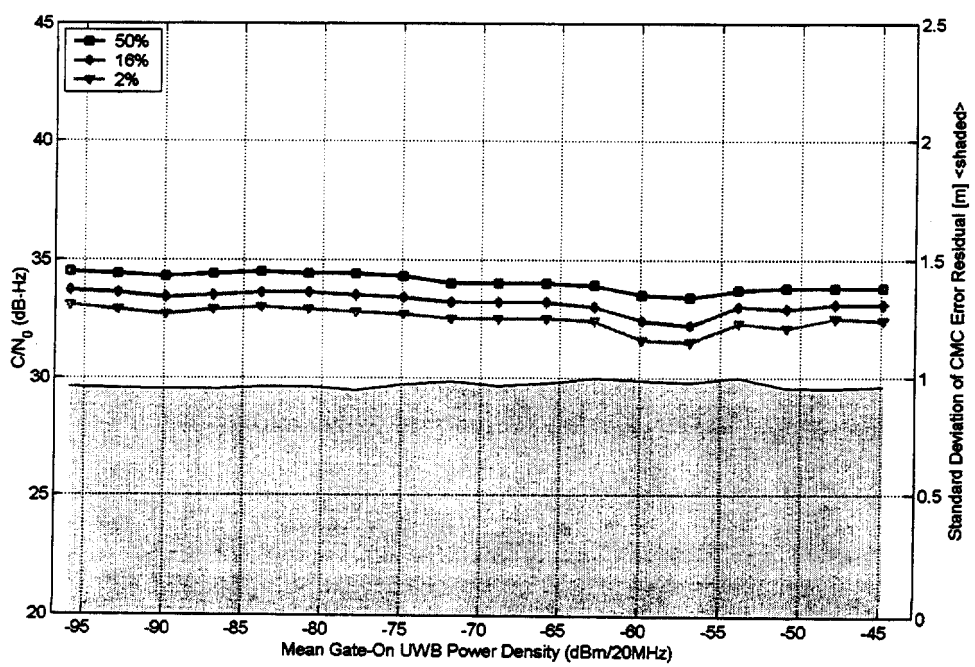

Figure B.1.7. Measured GPS parameters (Rx 3) as a function of 1-MHz PRF, UPS, gated (20% duty cycle) UWB interference.

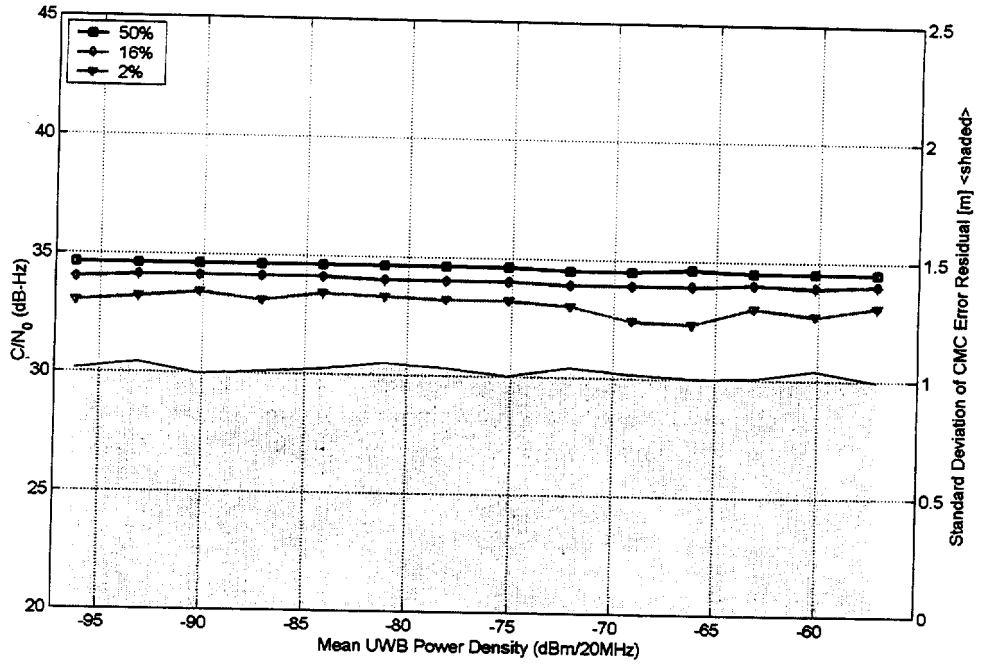

Figure B.1.8. Measured GPS parameters (Rx 3) as a function of 0.1-MHz PRF, UPS, non-gated UWB interference.

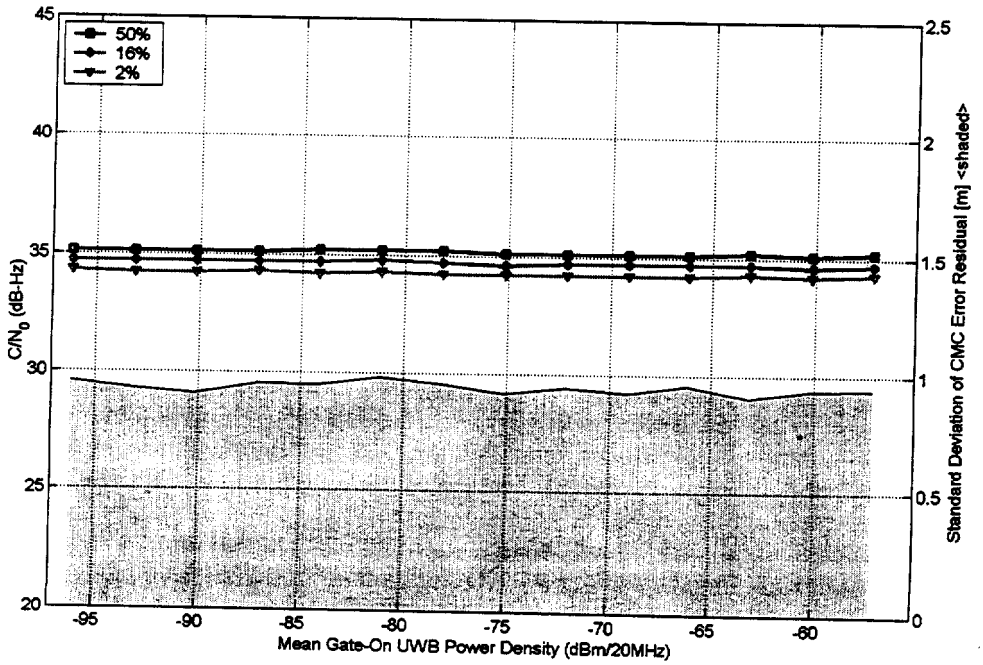

Figure B.1.9. Measured GPS parameters (Rx 3) as a function of 0.1-MHz PRF, UPS, gated (20% duty cycle) UWB interference.

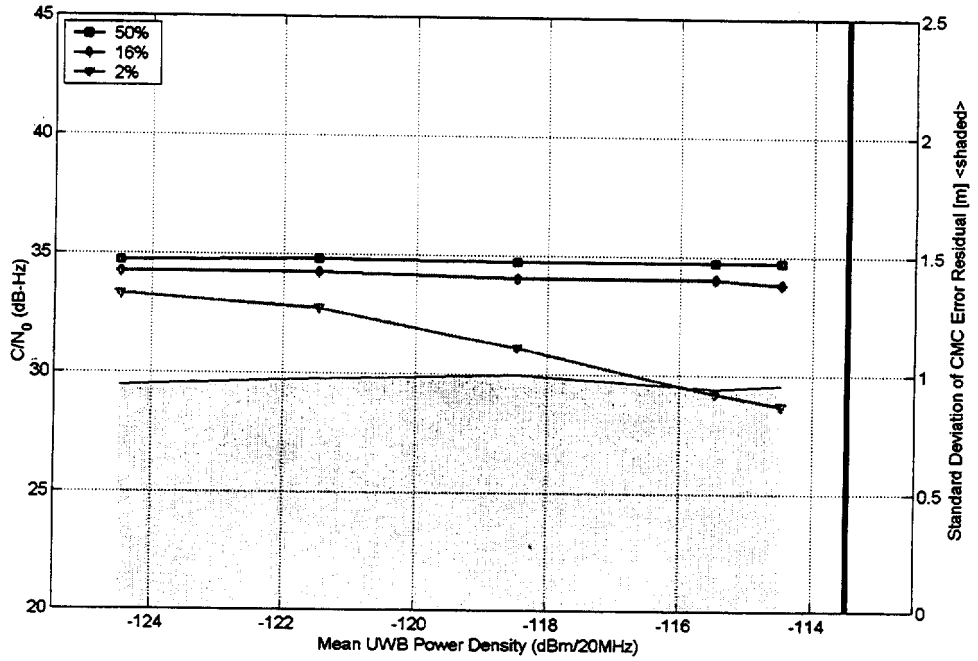

Figure B.1.10. Measured GPS parameters (Rx 3) as a function of 20-MHz PRF, OOK, non-gated UWB interference.

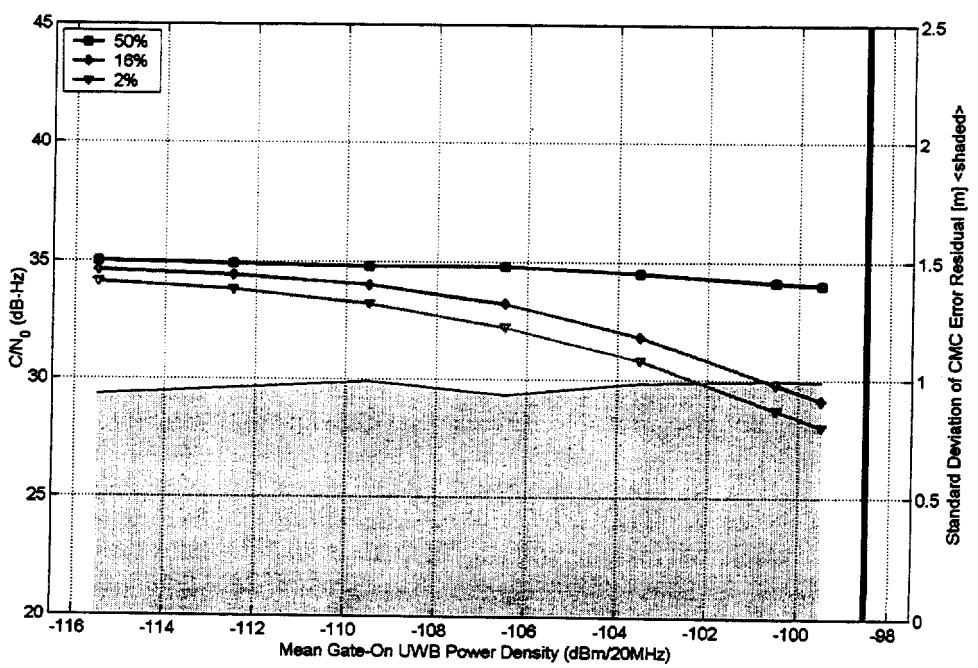

Figure B.1.11. Measured GPS parameters (Rx 3) as a function of 20-MHz PRF, OOK, gated (20% duty cycle) UWB interference.

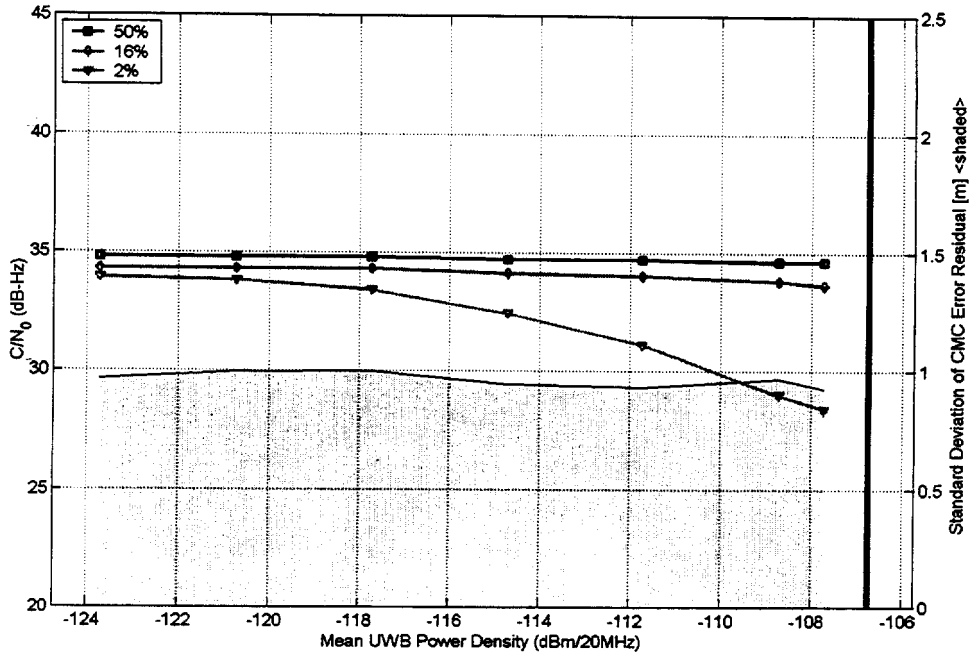

Figure B.1.12. Measured GPS parameters (Rx 3) as a function of 5-MHz PRF, OOK, non-gated UWB interference.

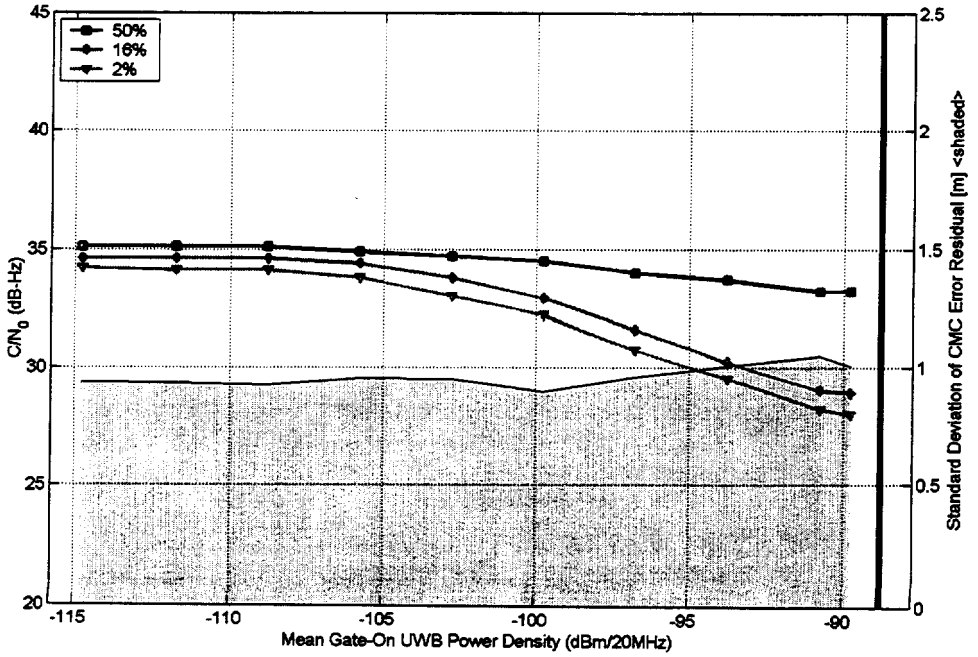

Figure B.1.13. Measured GPS parameters (Rx 3) as a function of 5-MHz PRF, OOK, gated (20% duty cycle) UWB interference.

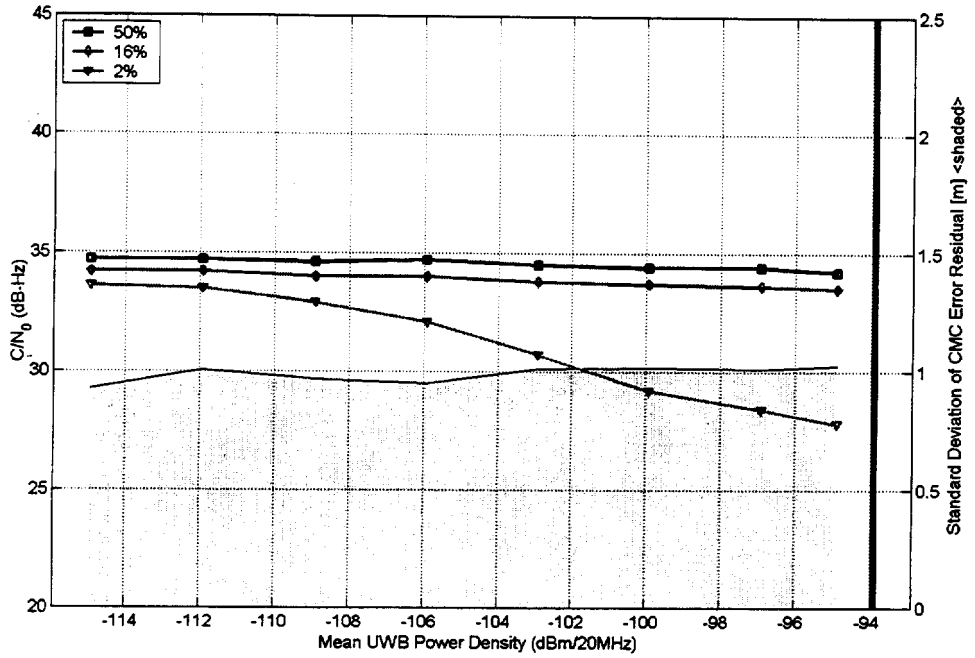

Figure B.1.14. Measured GPS parameters (Rx 3) as a function of 1-MHz PRF, OOK, non-gated UWB interference.

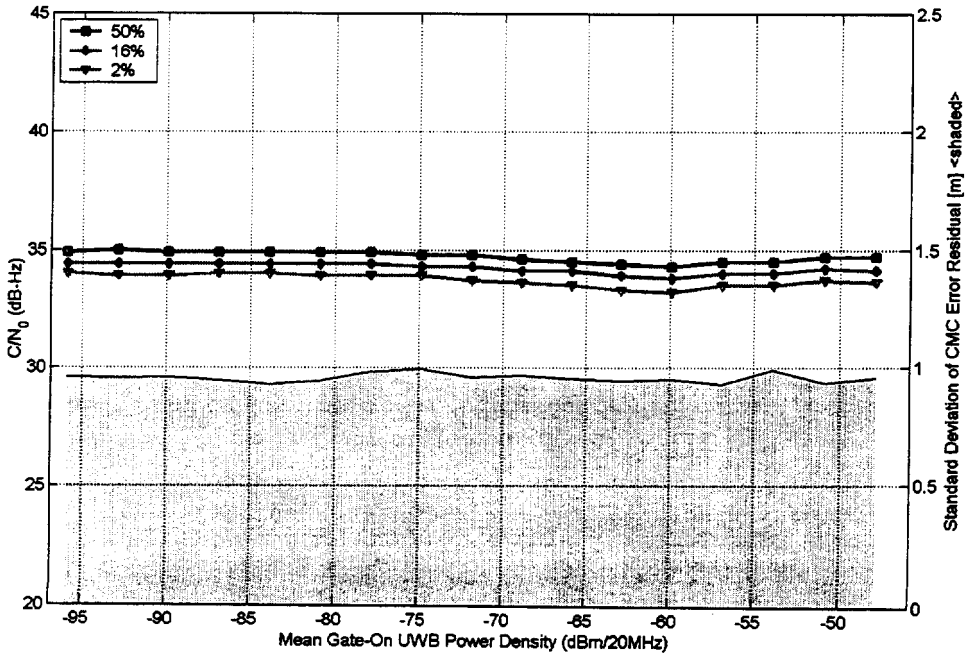

Figure B.1.15. Measured GPS parameters (Rx 3) as a function of 1-MHz PRF, OOK, gated (20% duty cycle) UWB interference.

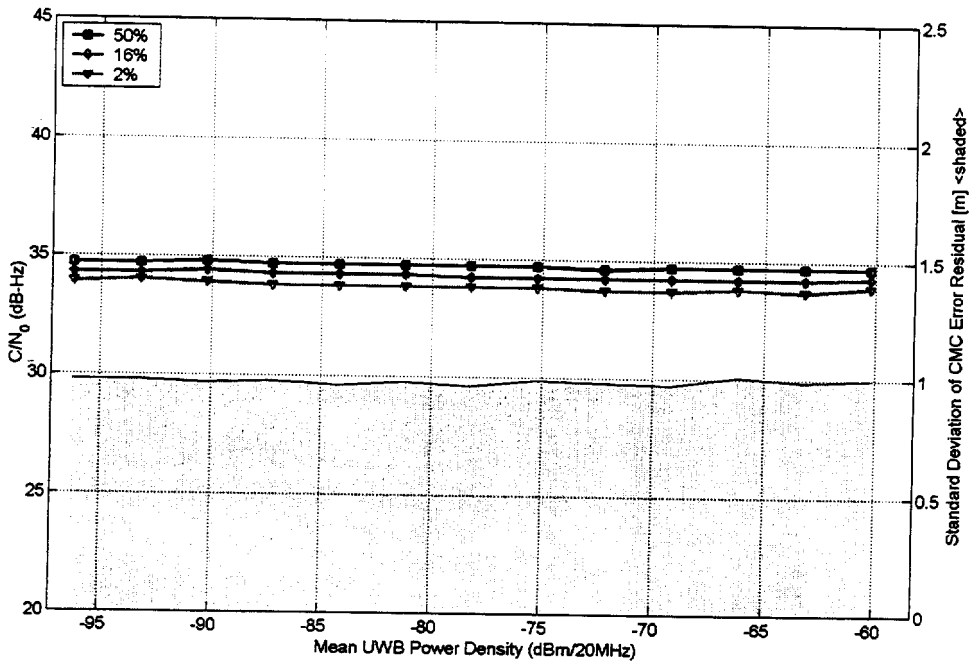

Figure B.1.16. Measured GPS parameters (Rx 3) as a function of 0.1-MHz PRF, OOK, non-gated UWB interference.

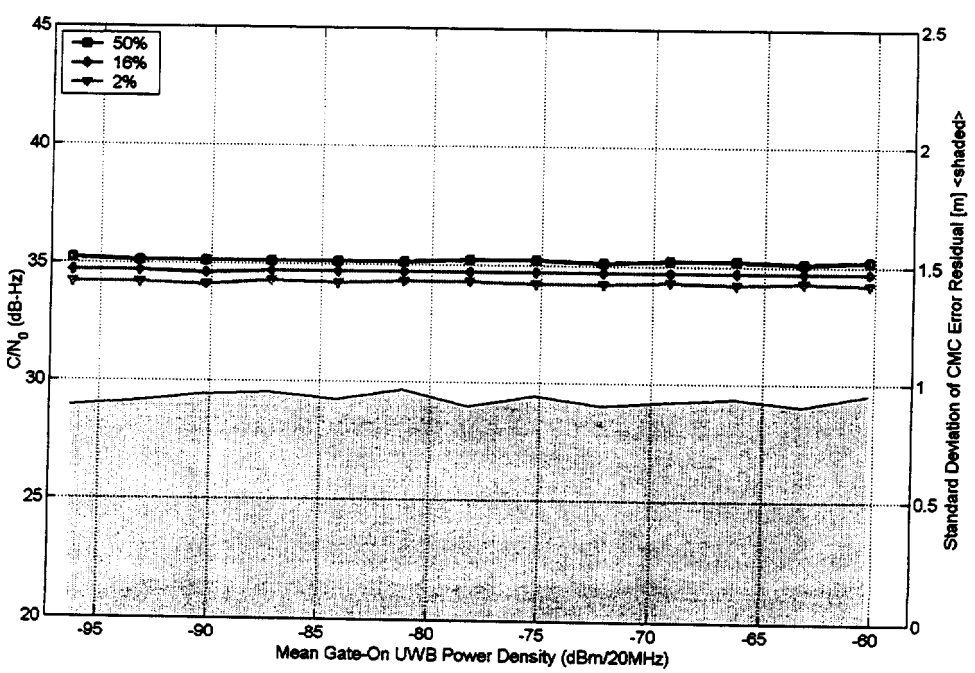

Figure B.1.17. Measured GPS parameters (Rx 3) as a function of 0.1-MHz PRF, OOK, gated (20% duty cycle) UWB interference.

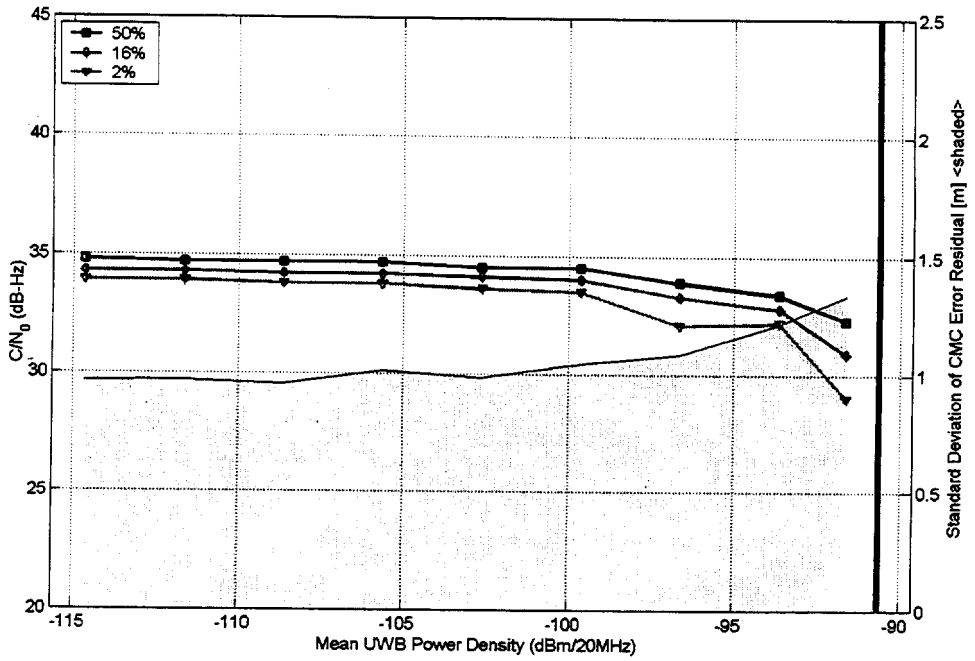

Figure B.1.18. Measured GPS parameters (Rx 3) as a function of 20-MHz PRF, 50%-ARD, non-gated UWB interference.

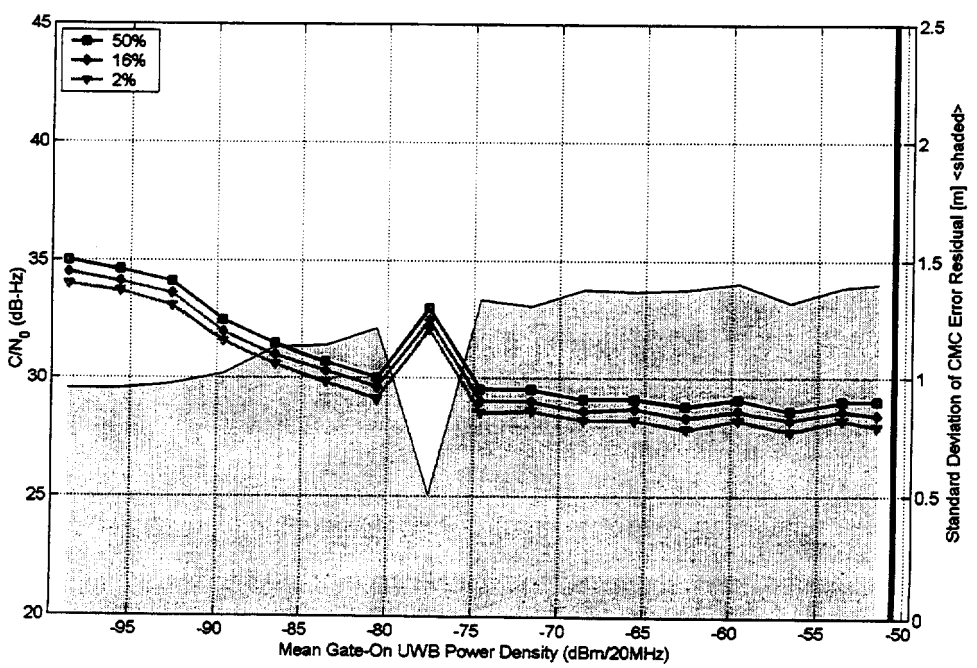

Figure B.1.19. Measured GPS parameters (Rx 3) as a function of 20-MHz PRF, 50%-ARD, gated (20% duty cycle) UWB interference.

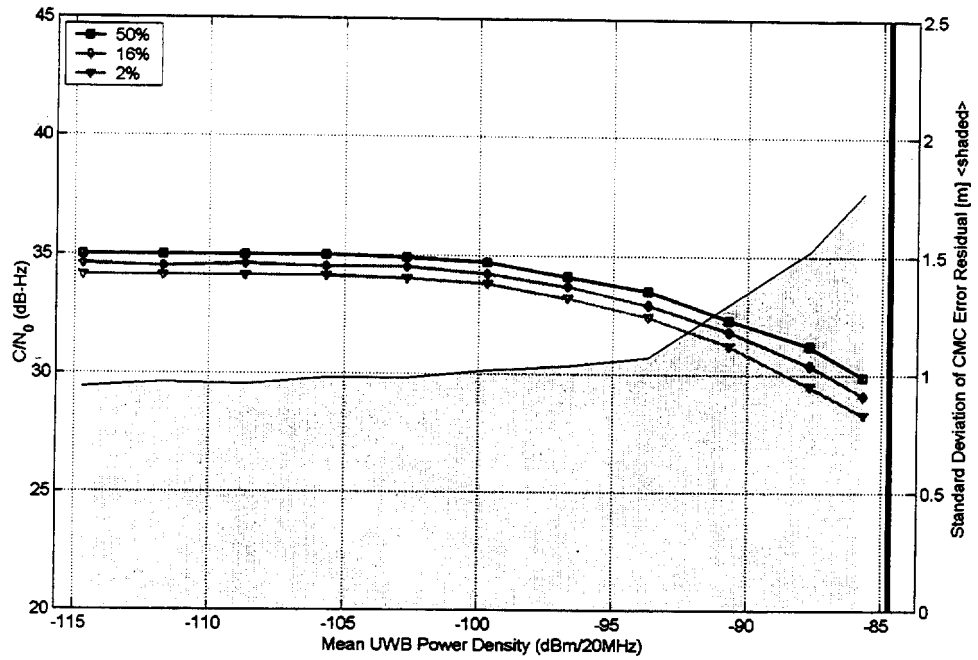

Figure B.1.20. Measured GPS parameters (Rx 3) as a function of 5-MHz PRF, 50%-ARD, non-gated UWB interference.

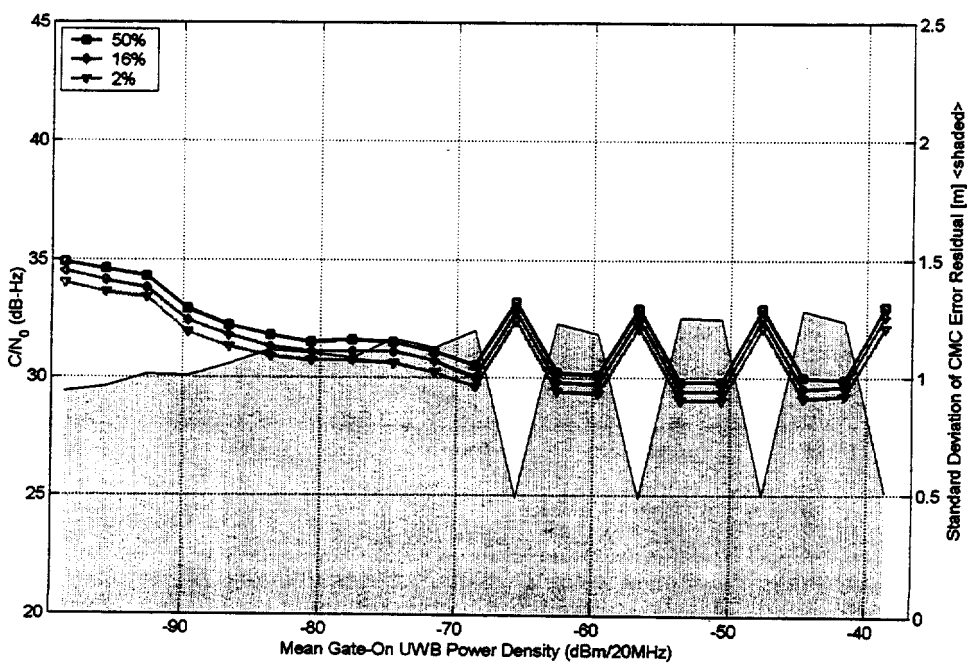

Figure B.1.21. Measured GPS parameters (Rx 3) as a function of 5-MHz PRF, 50%-ARD, gated (20% duty cycle) UWB interference.

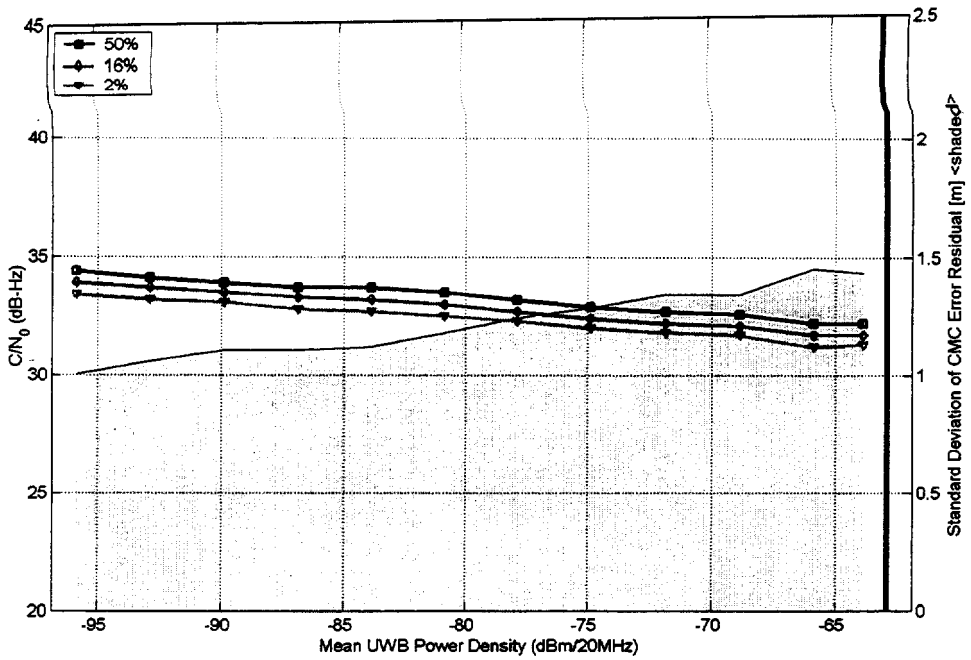

Figure B.1.22. Measured GPS parameters (Rx 3) as a function of 1-MHz PRF, 50% ARD, non-gated UWB interference.

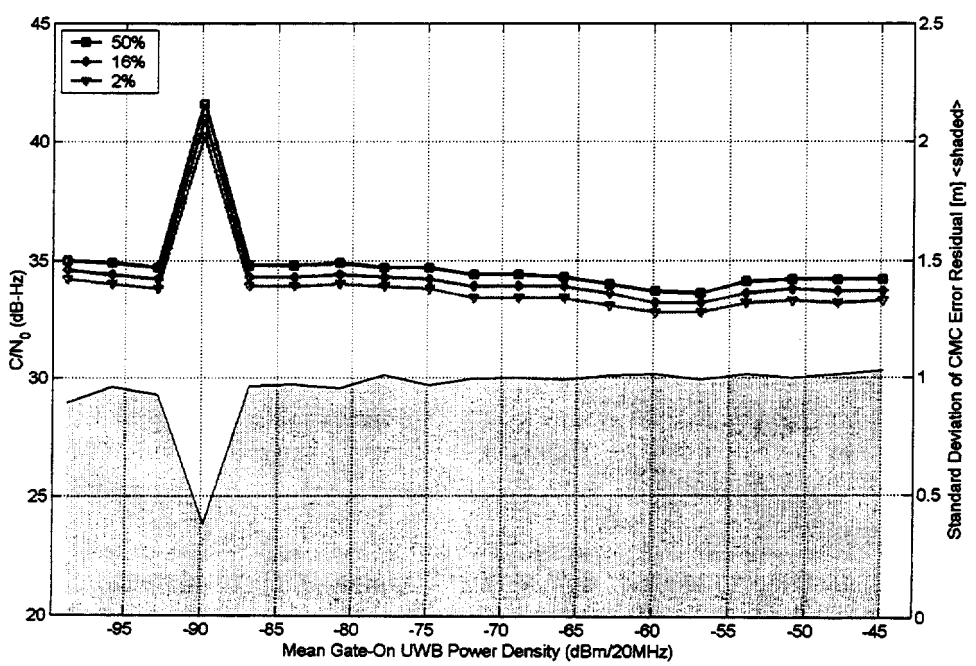

Figure B.1.23. Measured GPS parameters (Rx 3) as a function of 1-MHz PRF, 50% ARD, gated (20% duty cycle) UWB interference.

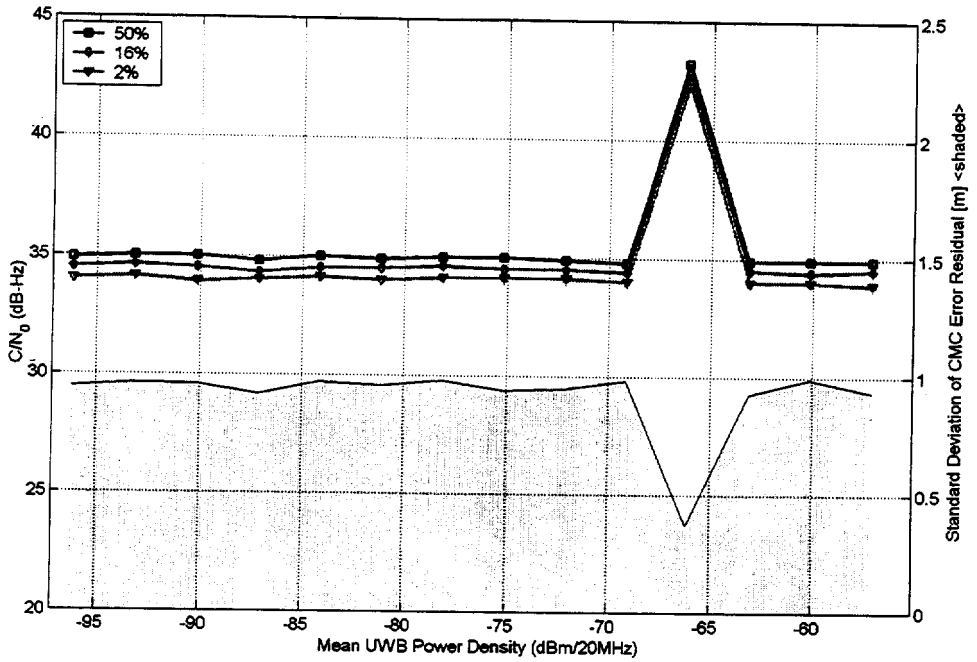

Figure B.1.24. Measured GPS parameters (Rx 3) as a function of 0.1-MHz PRF, 50% ARD, non-gated UWB interference.

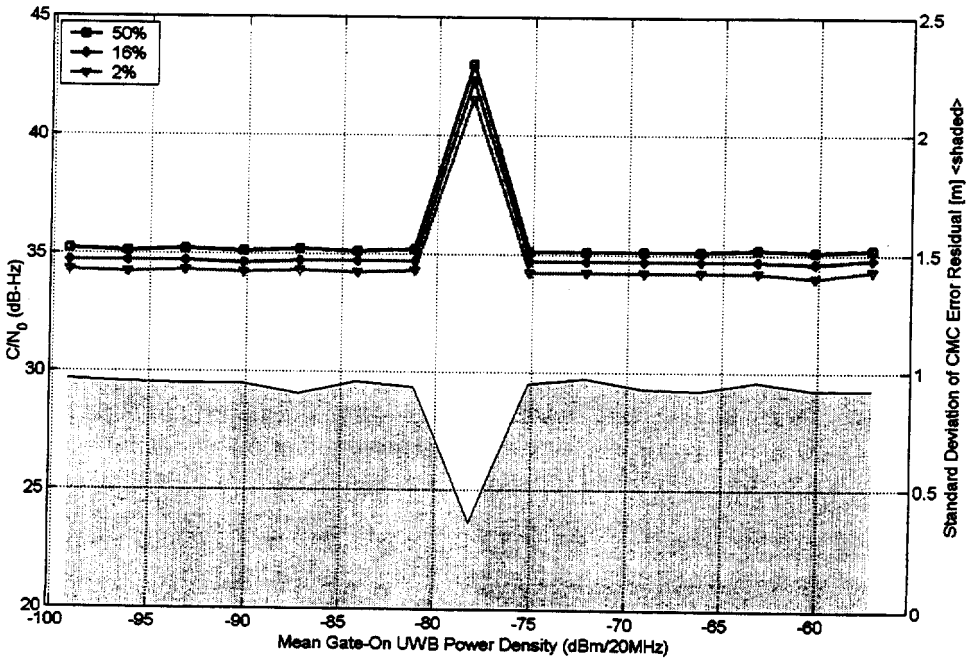

Figure B.1.25. Measured GPS parameters (Rx 3) as a function of 0.1-MHz PRF, 50% ARD, gated (20% duty cycle) UWB interference.

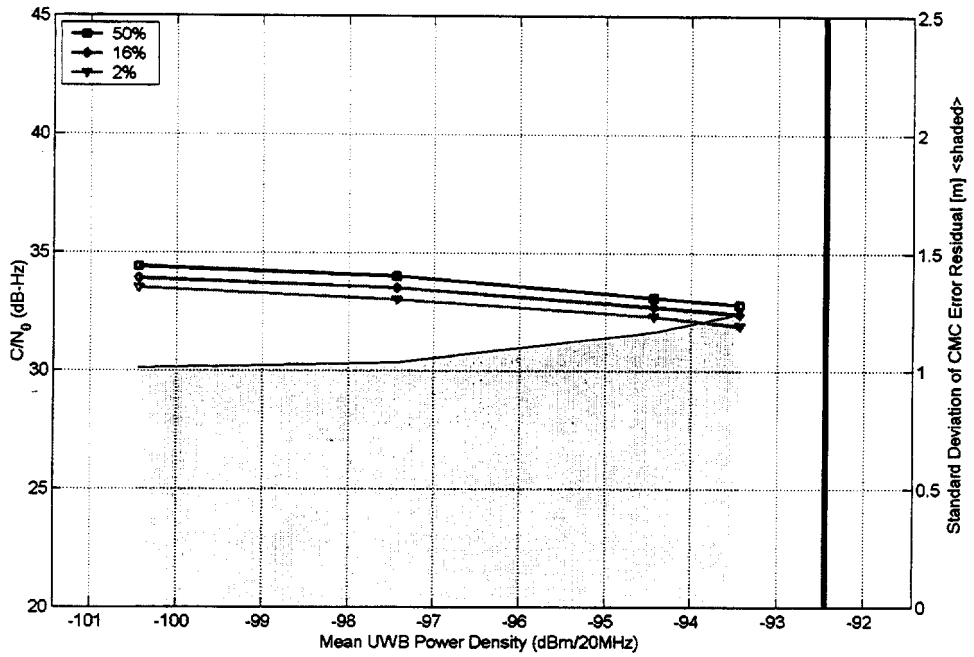

Figure B.1.26. Measured GPS parameters (Rx 3) as a function of 20-MHz PRF, 2% RRD, non-gated UWB interference.

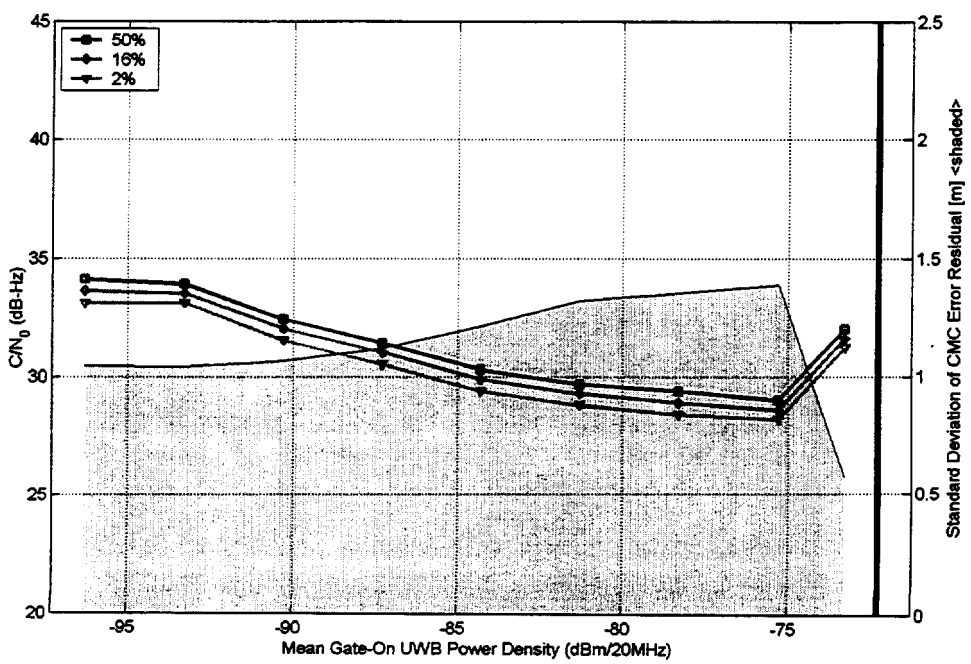

Figure B.1.27. Measured GPS parameters (Rx 3) as a function of 20-MHz PRF, 2% RRD, gated (20% duty cycle) UWB interference.

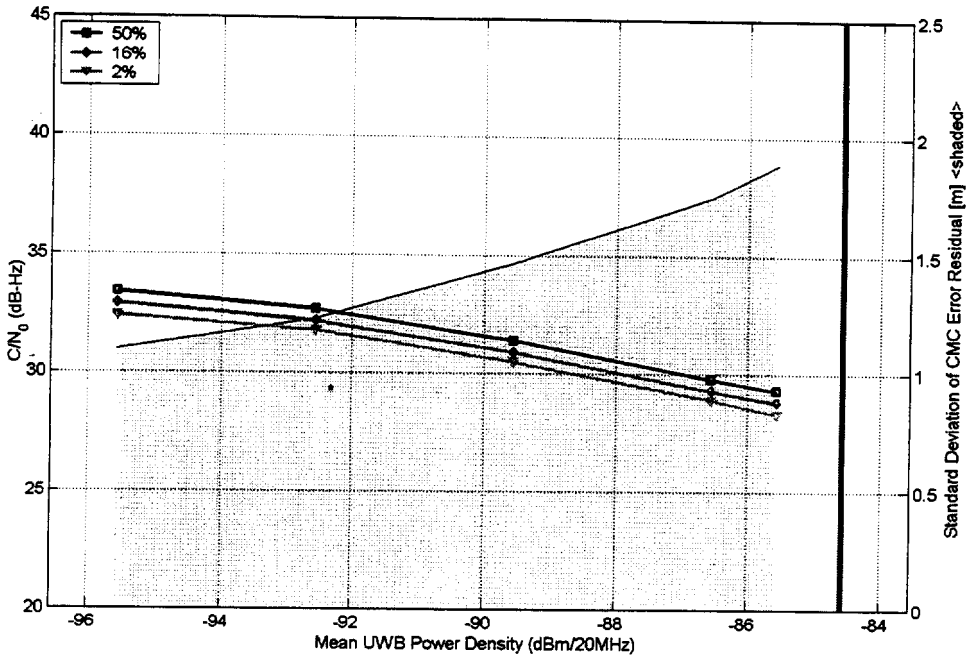

Figure B.1.28. Measured GPS parameters (Rx 3) as a function of 5-MHz PRF, 2% RRD, non-gated UWB interference.

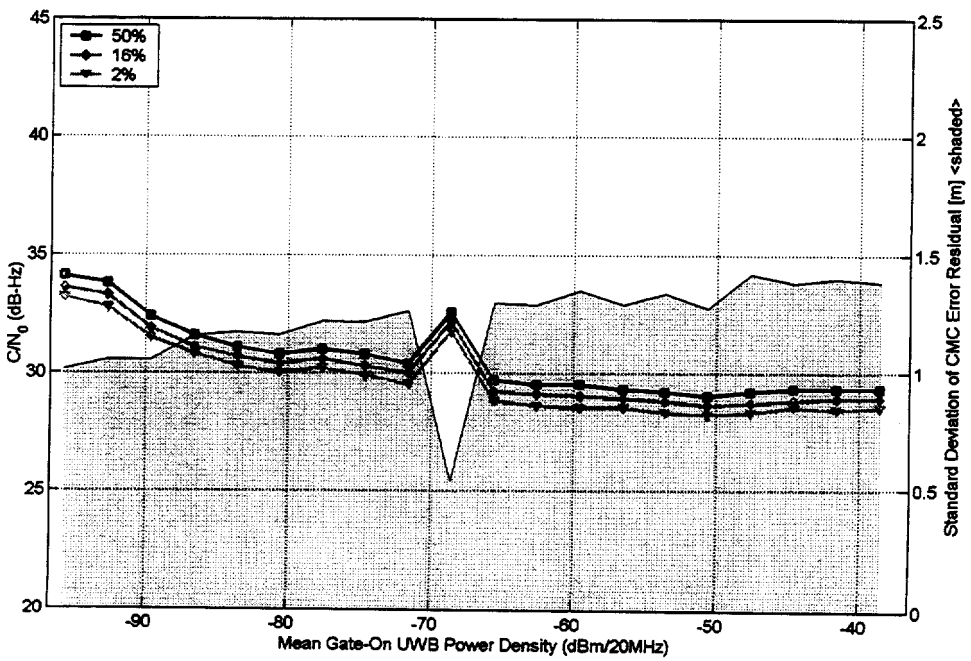

Figure B.1.29. Measured GPS parameters (Rx 3) as a function of 5-MHz PRF, 2% RRD, gated (20% duty cycle) UWB interference.

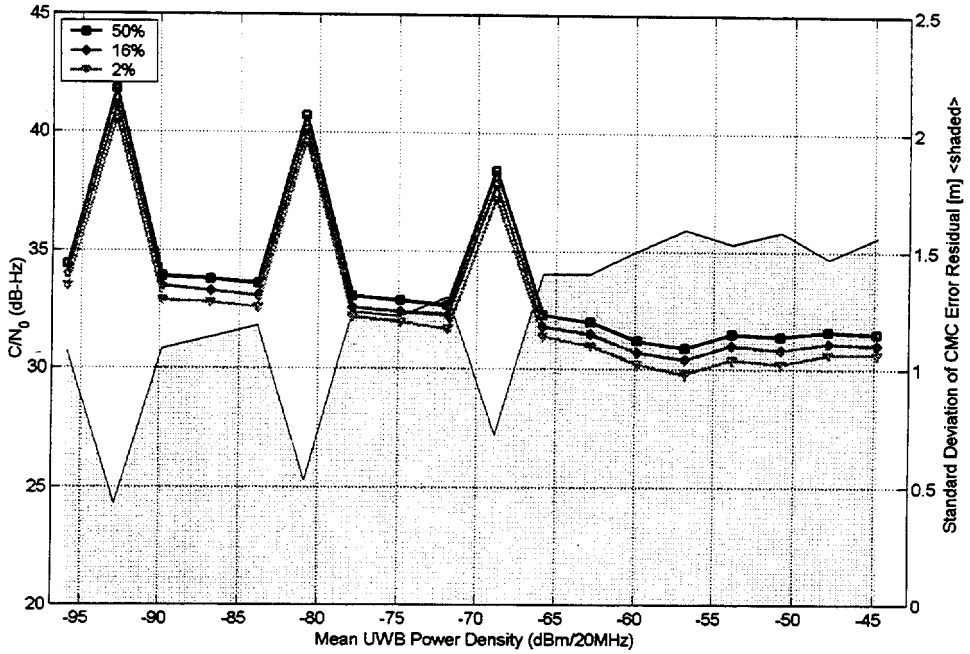

Figure B.1.30. Measured GPS parameters (Rx 3) as a function of 1-MHz PRF, 2% RRD, non-gated UWB interference.

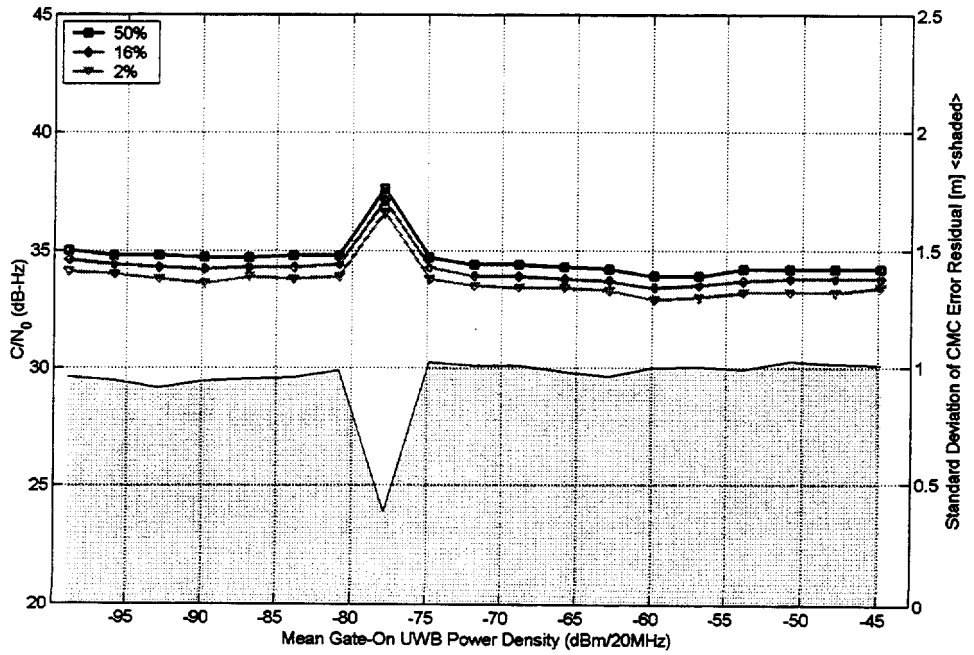

Figure B.1.31. Measured GPS parameters (Rx 3) as a function of 1-MHz PRF, 2% RRD, gated (20% duty cycle) UWB interference.

B.2. TSO-C129a Aviation Receiver (Rx 4) Results

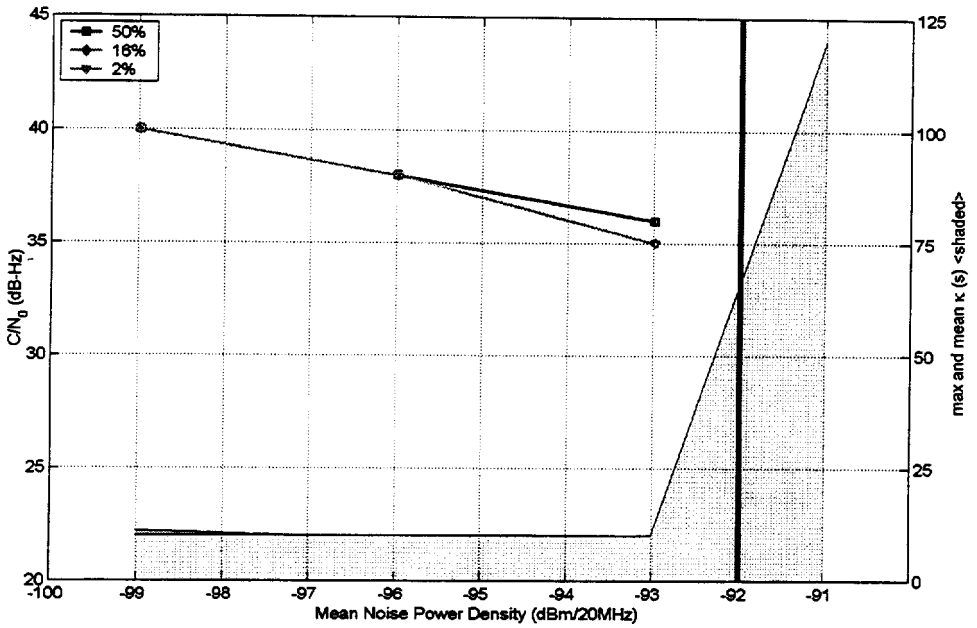

Figure B.2.1. Measured GPS parameters (Rx 4) as a function of Gaussian-noise interference.

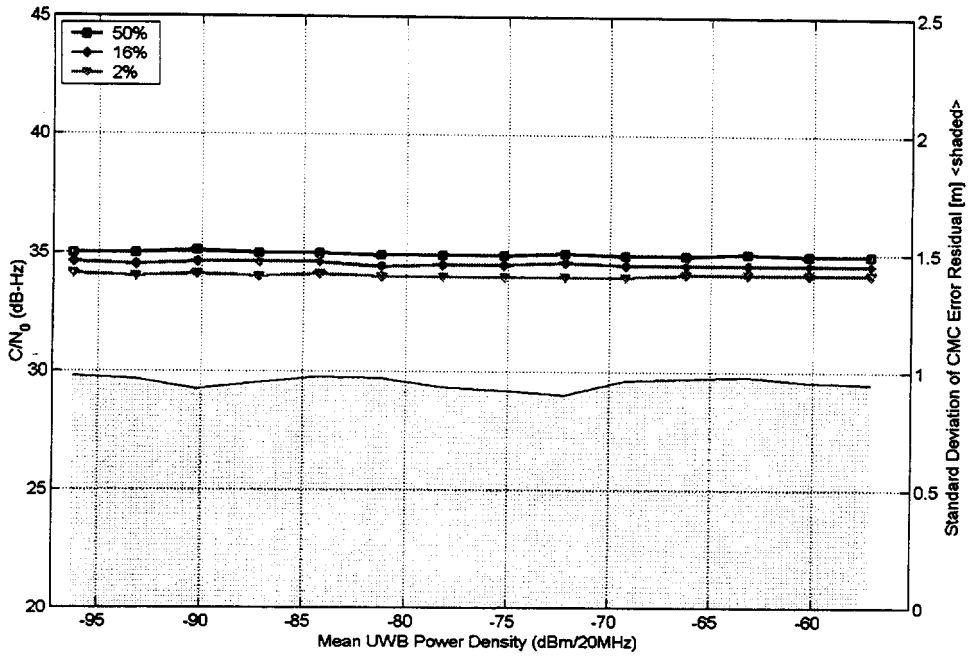

Figure B.1.32. Measured GPS parameters (Rx 3) as a function of 0.1-MHz PRF, 2% RRD, non-gated UWB interference.

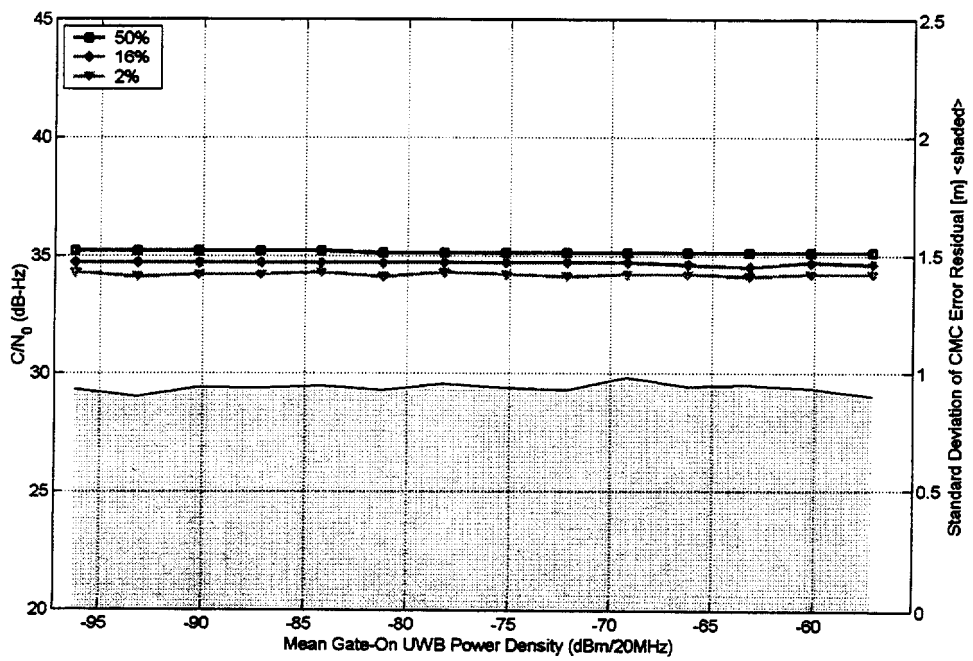

Figure B.1.33. Measured GPS parameters (Rx 3) as a function of 0.1-MHz PRF, 2% RRD, gated (20% duty cycle) UWB interference.

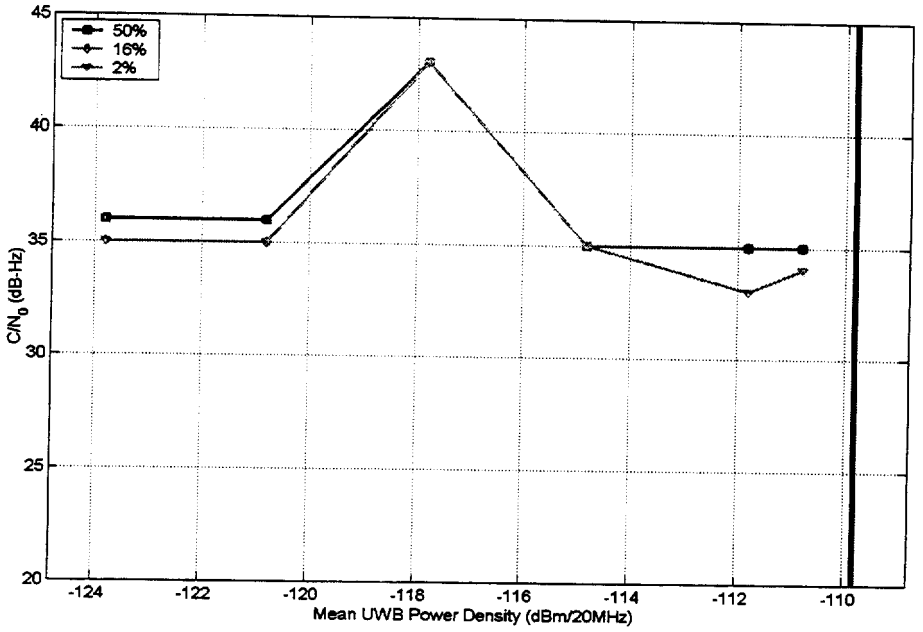

Figure B.2.2. Measured GPS parameters (Rx 4) as a function of 20-MHz PRF, UPS, non-gated UWB interference.

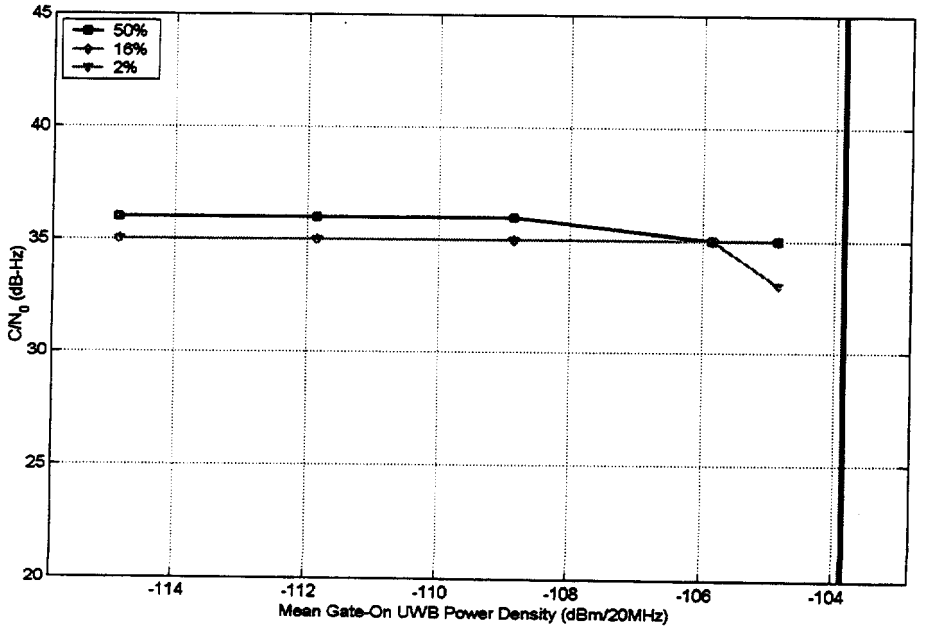

Figure B.2.3. Measured GPS parameters (Rx 4) as a function of 20-MHz PRF, UPS, gated (20% duty cycle) UWB interference.

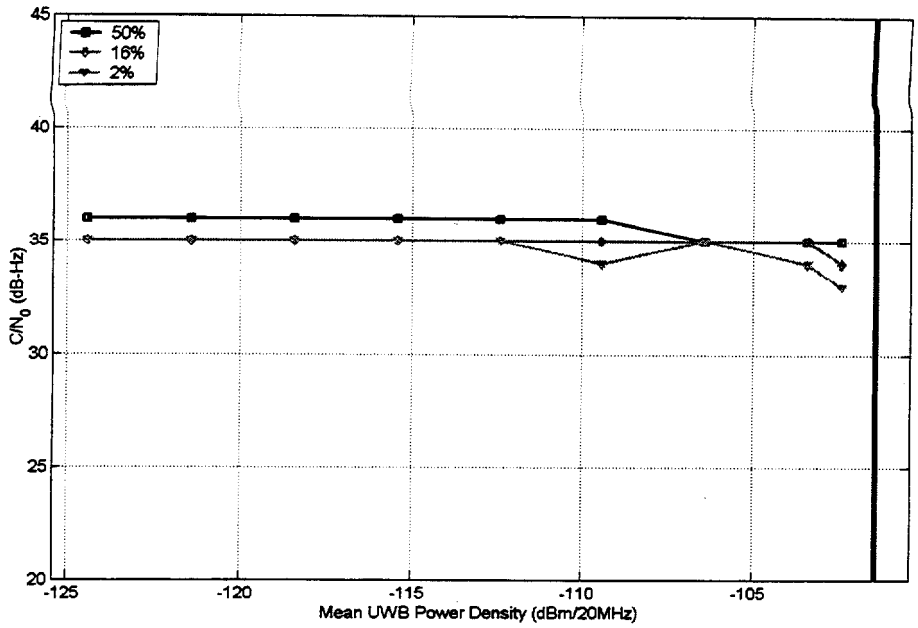

Figure B.2.4. Measured GPS parameters (Rx 4) as a function of 5-MHz PRF, UPS, non-gated UWB interference.

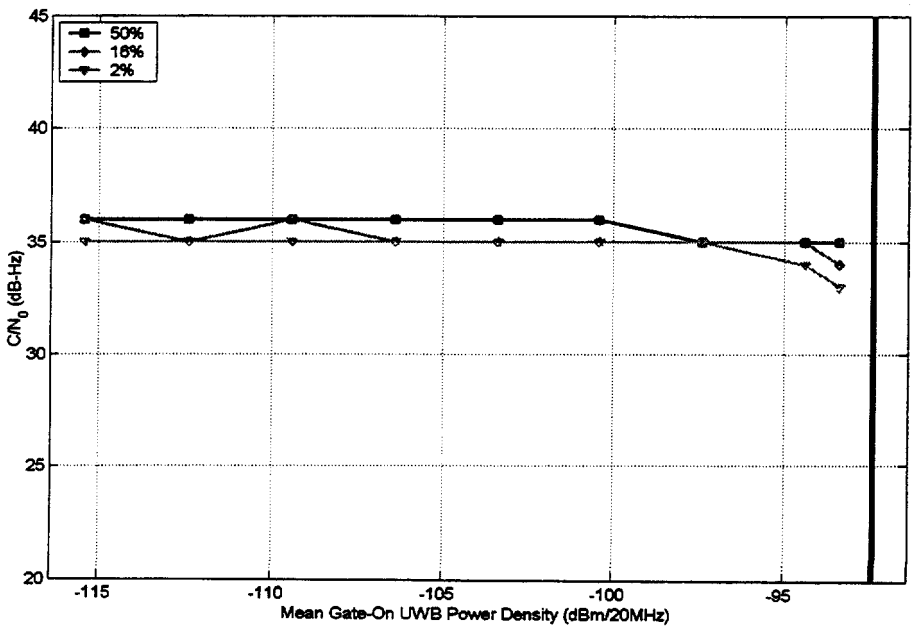

Figure B.2.5. Measured GPS parameters (Rx 4) as a function of 5-MHz PRF, UPS, gated (20% duty cycle) UWB interference.

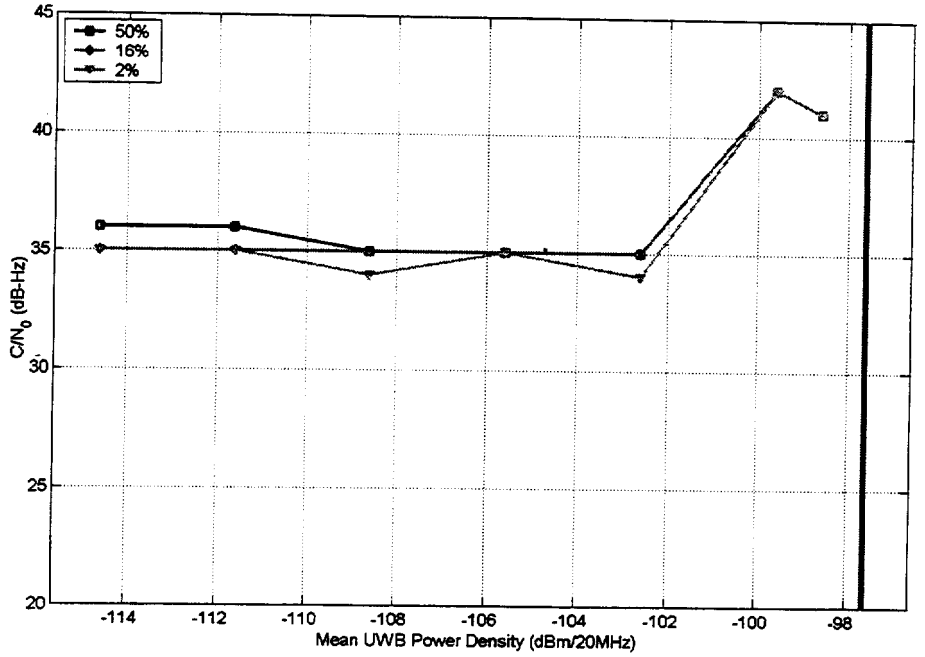

Figure B.2.6. Measured GPS parameters (Rx 4) as a function of 1-MHz PRF, UPS, non-gated UWB interference.

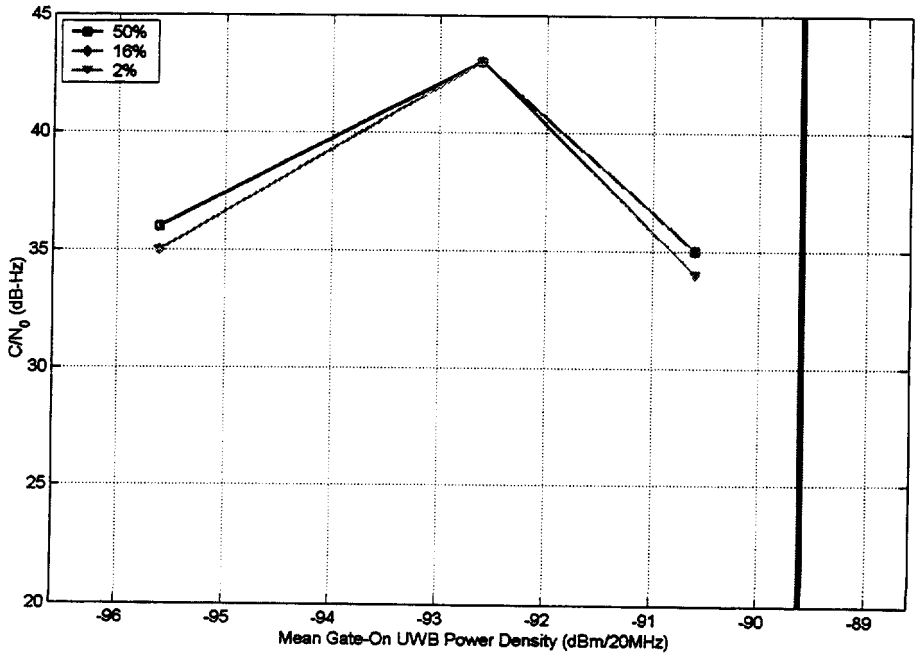

Figure B.2.7. Measured GPS parameters (Rx 4) as a function of 1-MHz PRF, UPS, gated (20% duty cycle) UWB interference.

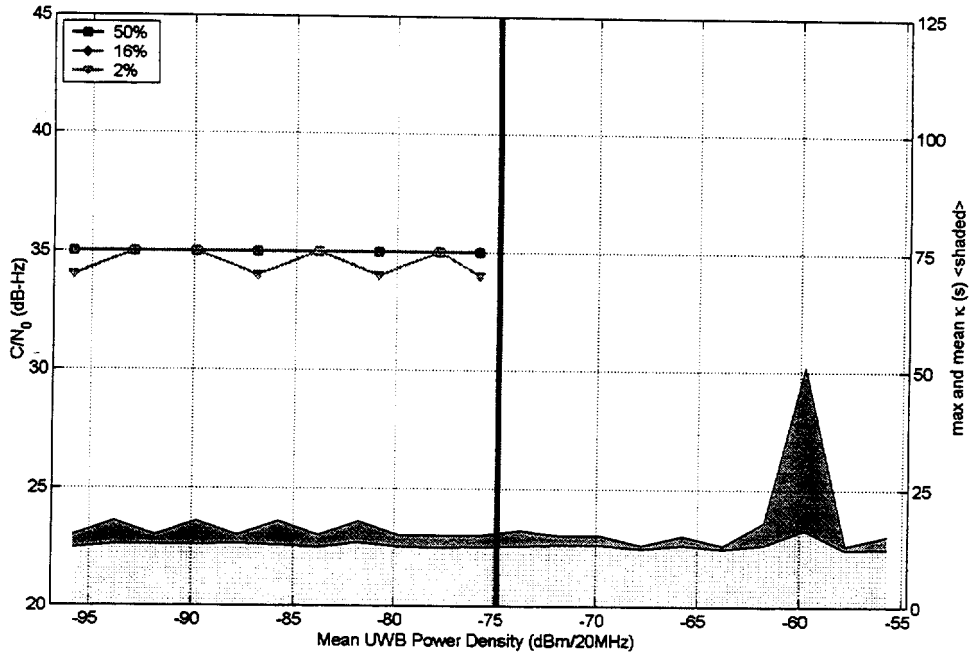

Figure B.2.8. Measured GPS parameters (Rx 4) as a function of 0.1-MHz PRF, UPS, non-gated UWB interference.

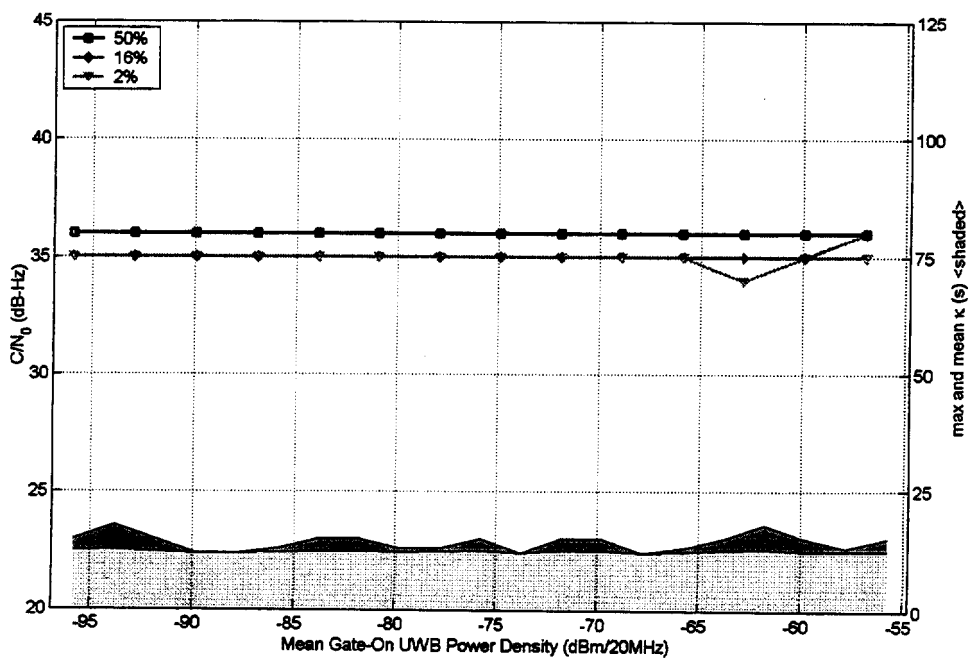

Figure B.2.9. Measured GPS parameters (Rx 4) as a function of 0.1-MHz PRF, UPS, gated (20% duty cycle) UWB interference.

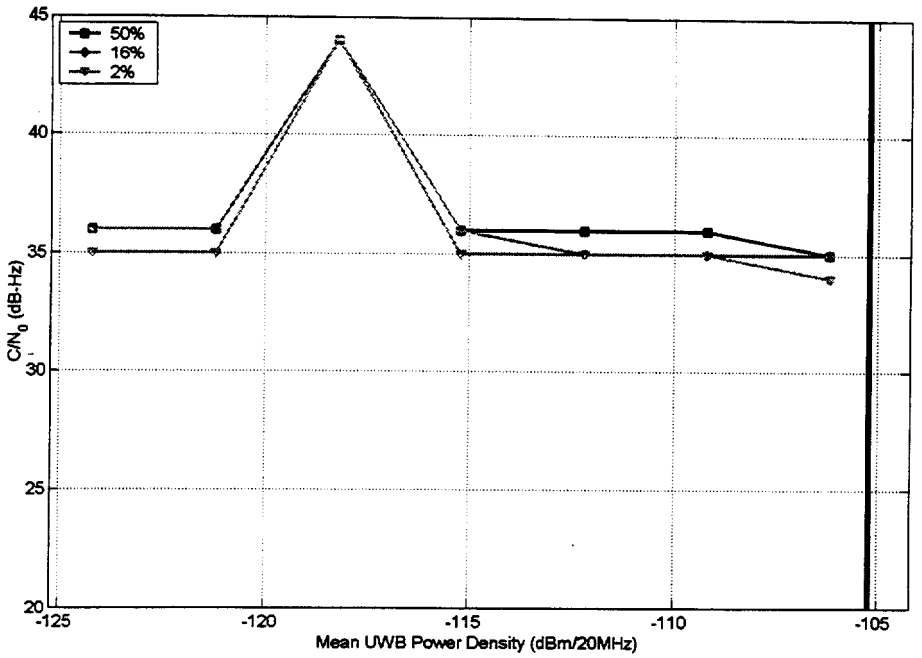

Figure B.2.10. Measured GPS parameters (Rx 4) as a function of 20-MHz PRF, OOK, non-gated UWB interference.

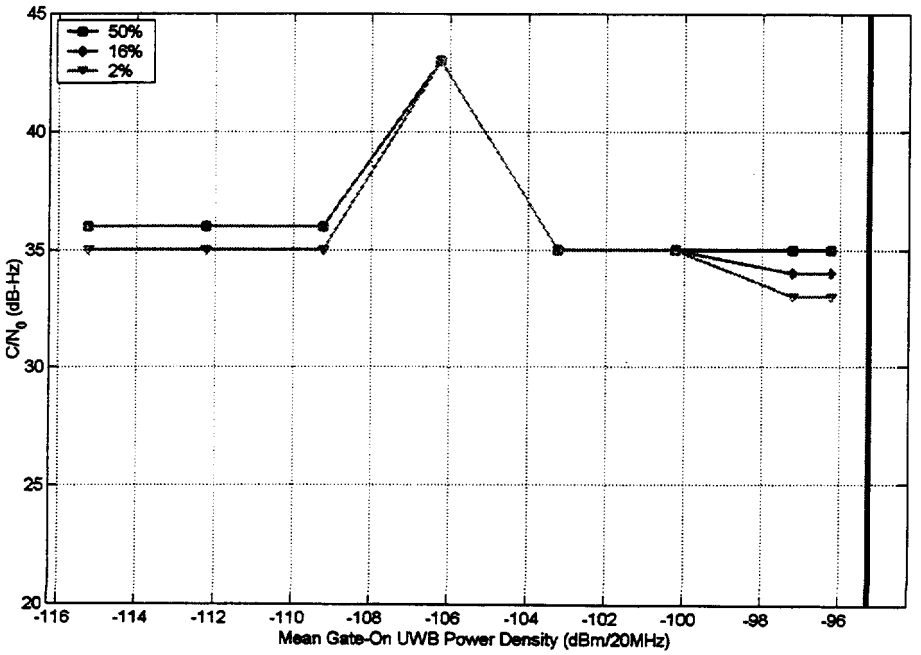

Figure B.2.11. Measured GPS parameters (Rx 4) as a function of 20-MHz PRF, OOK, gated (20% duty cycle) UWB interference.

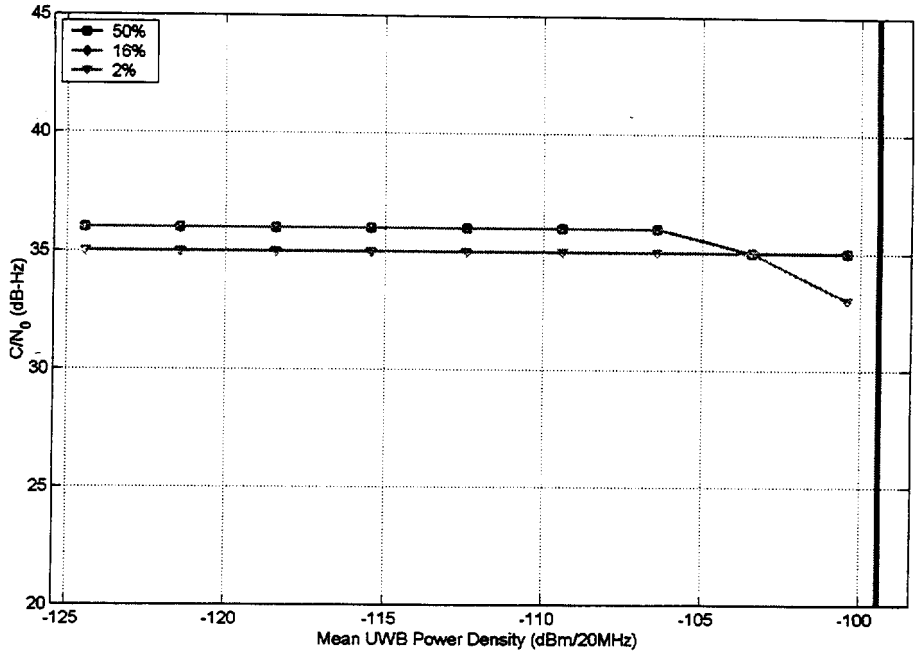

Figure B.2.12. Measured GPS parameters (Rx 4) as a function of 5-MHz PRF, OOK, non-gated UWB interference.

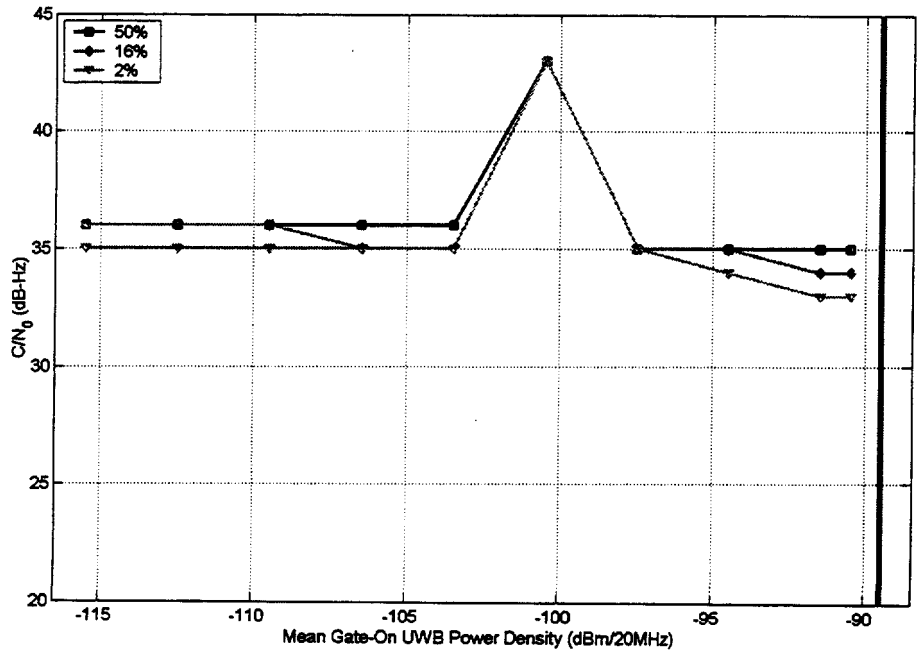

Figure B.2.13. Measured GPS parameters (Rx 4) as a function of 5-MHz PRF, OOK, gated (20% duty cycle) UWB interference.

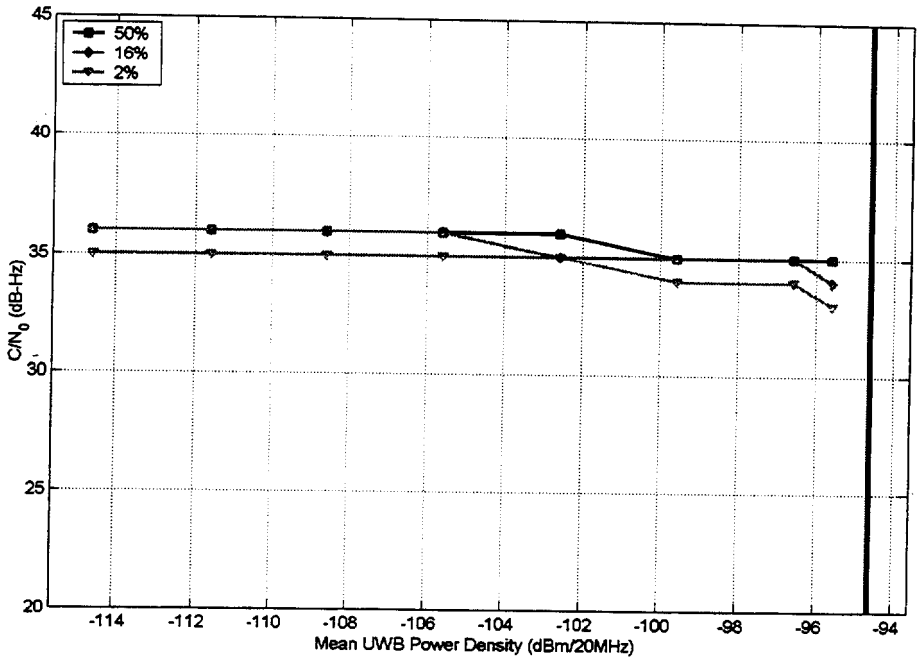

Figure B.2.14. Measured GPS parameters (Rx 4) as a function of 1-MHz PRF, OOK, non-gated UWB interference.

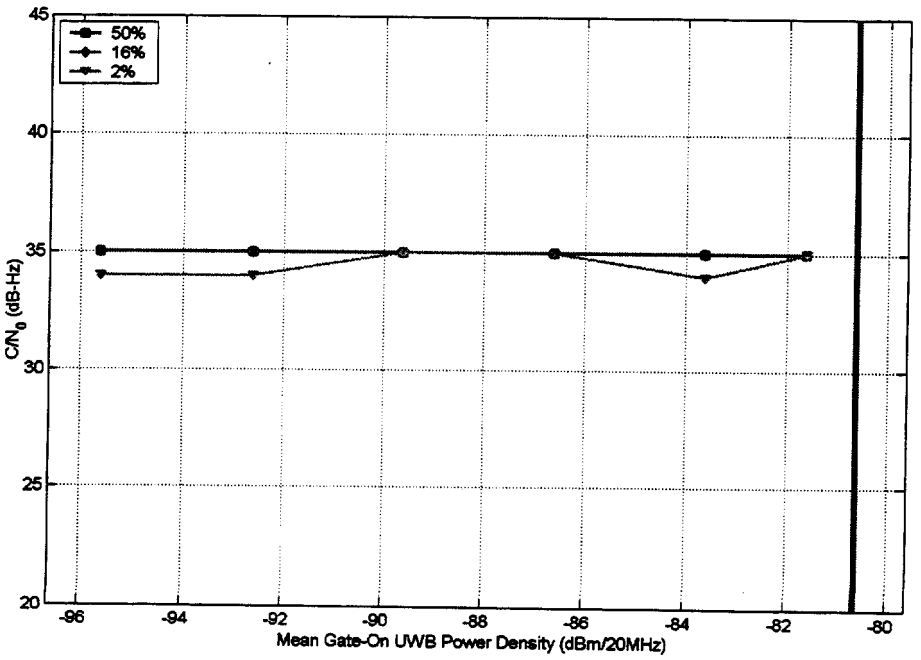

Figure B.2.15. Measured GPS parameters (Rx 4) as a function of 1-MHz PRF, OOK, gated (20% duty cycle) UWB interference.

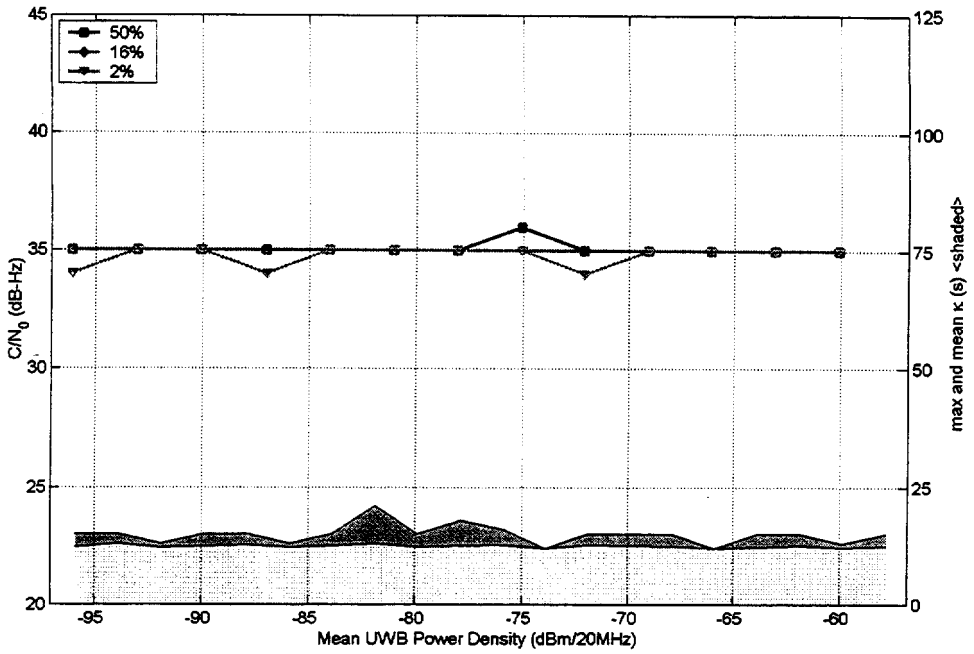

Figure B.2.16. Measured GPS parameters (Rx 4) as a function of 0.1-MHz PRF, OOK, non-gated UWB interference.

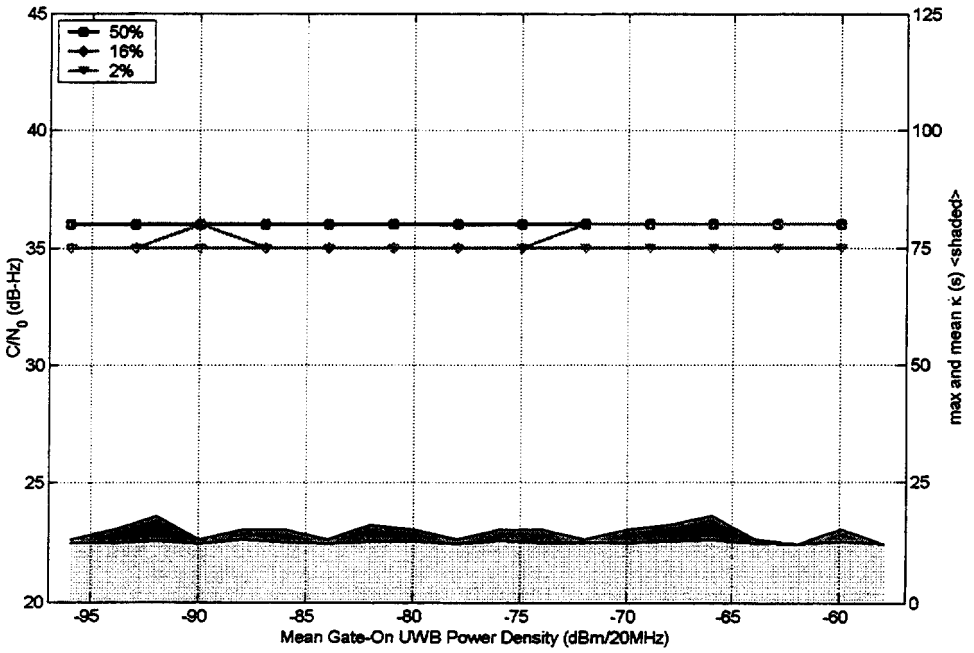

Figure B.2.17. Measured GPS parameters (Rx 4) as a function of 0.1-MHz PRF, OOK, gated (20% duty cycle) UWB interference.

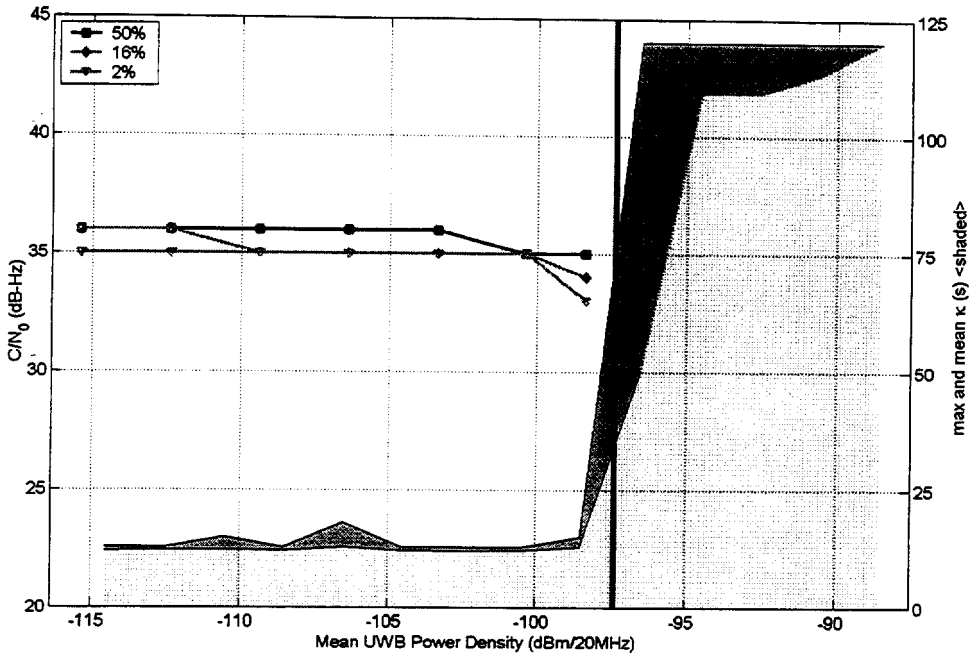

Figure B.2.18. Measured GPS parameters (Rx 4) as a function of 20-MHz PRF, 50% ARD, non-gated UWB interference.

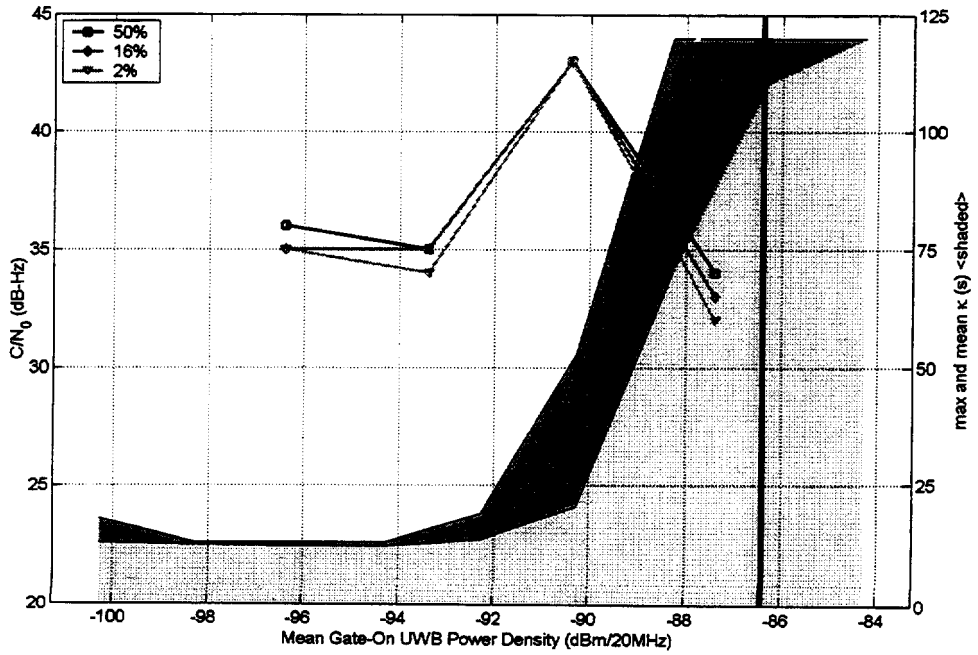

Figure B.2.19. Measured GPS parameters (Rx 4) as a function of 20-MHz PRF, 50% ARD, gated (20% duty cycle) UWB interference.

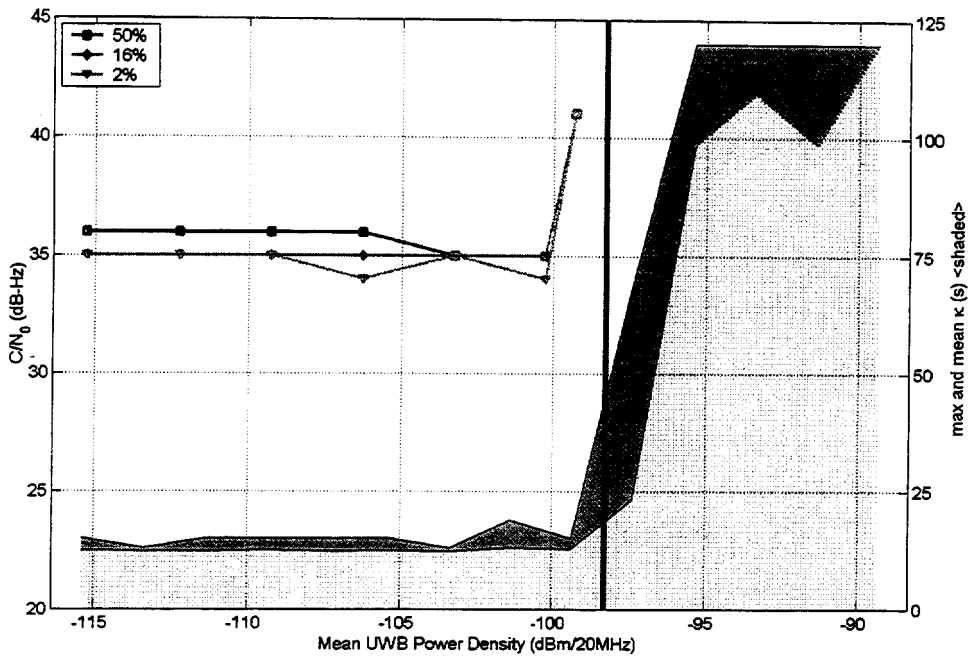

Figure B.2.20. Measured GPS parameters (Rx 4) as a function of 5-MHz PRF, 50% ARD, non-gated UWB interference.

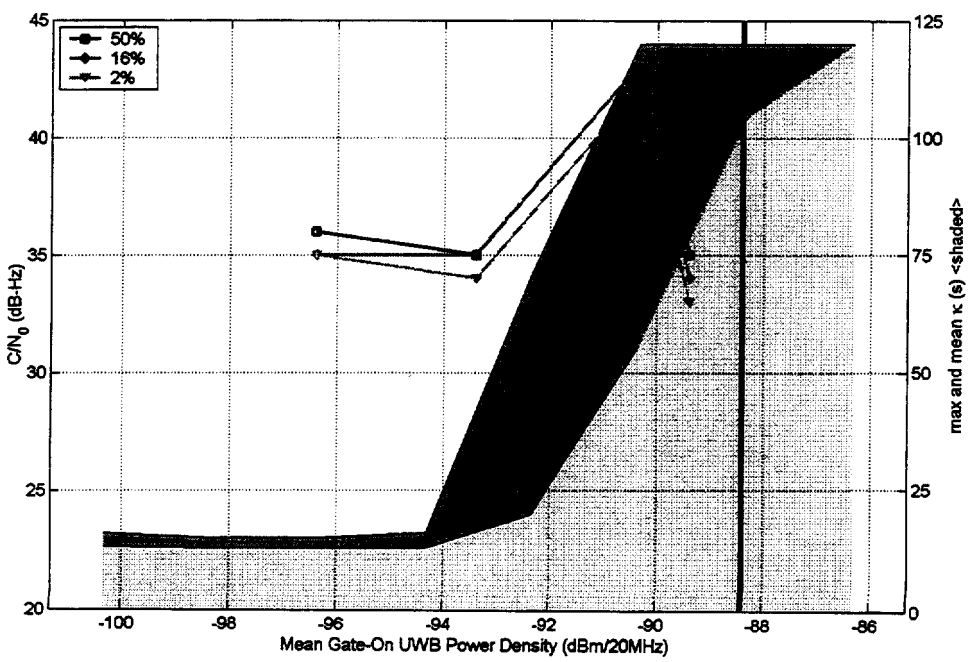

Figure B.2.21. Measured GPS parameters (Rx 4) as a function of 5-MHz PRF, 50% ARD, gated (20% duty cycle) UWB interference.

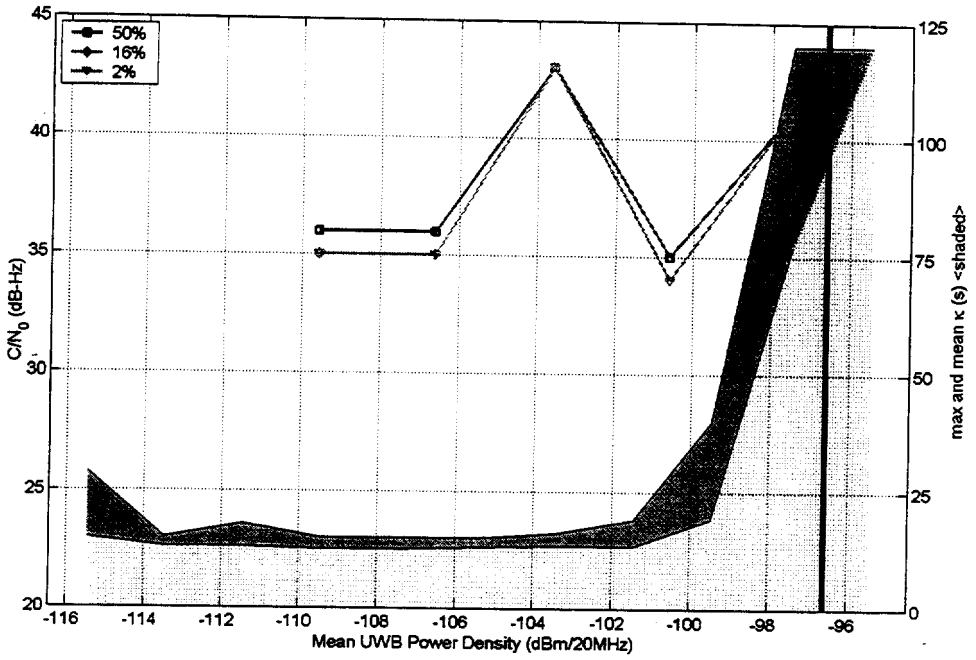

Figure B.2.22. Measured GPS parameters (Rx 4) as a function of 1-MHz PRF, 50% ARD, non-gated UWB interference.

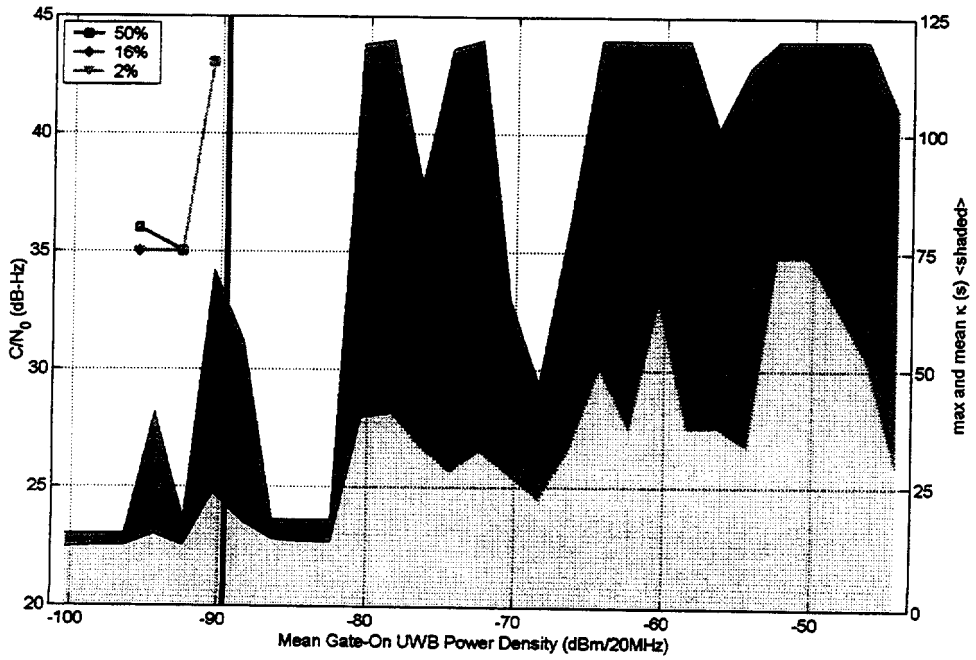

Figure B.2.23. Measured GPS parameters (Rx 4) as a function of 1-MHz PRF, 50% ARD, gated (20% duty cycle) UWB interference.

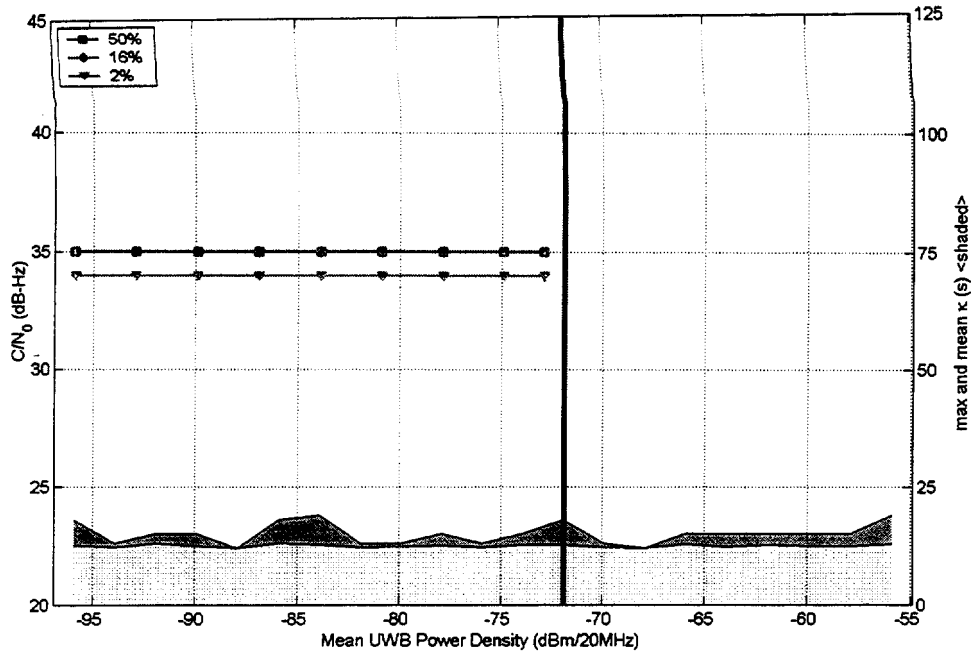

Figure B.2.24. Measured GPS parameters (Rx 4) as a function of 0.1-MHz PRF, 50% ARD, non-gated UWB interference.

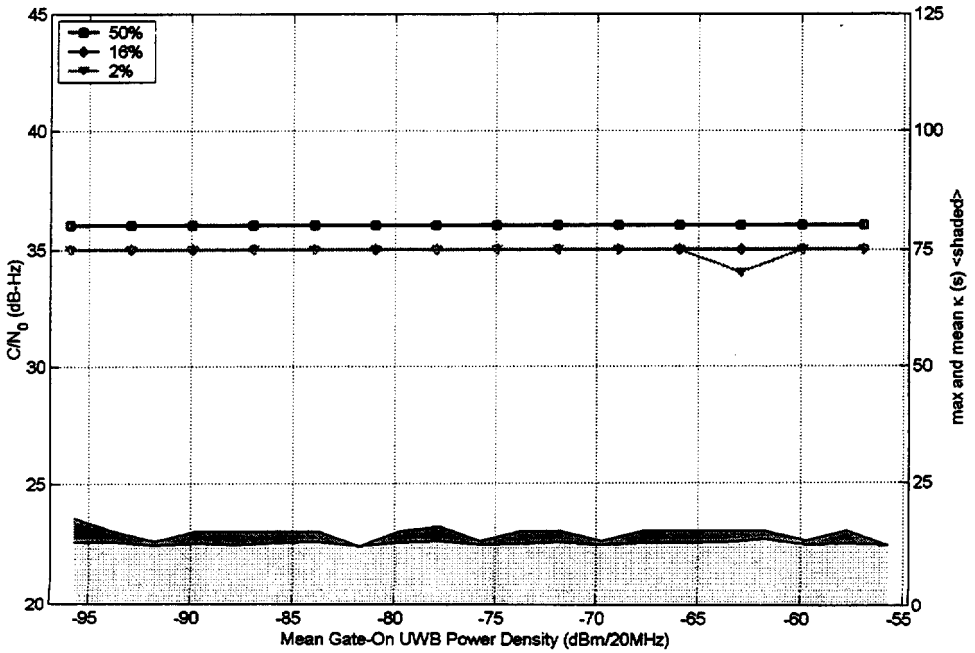

Figure B.2.25. Measured GPS parameters (Rx 4) as a function of 0.1-MHz PRF, 50% ARD, gated (20% duty cycle) UWB interference.

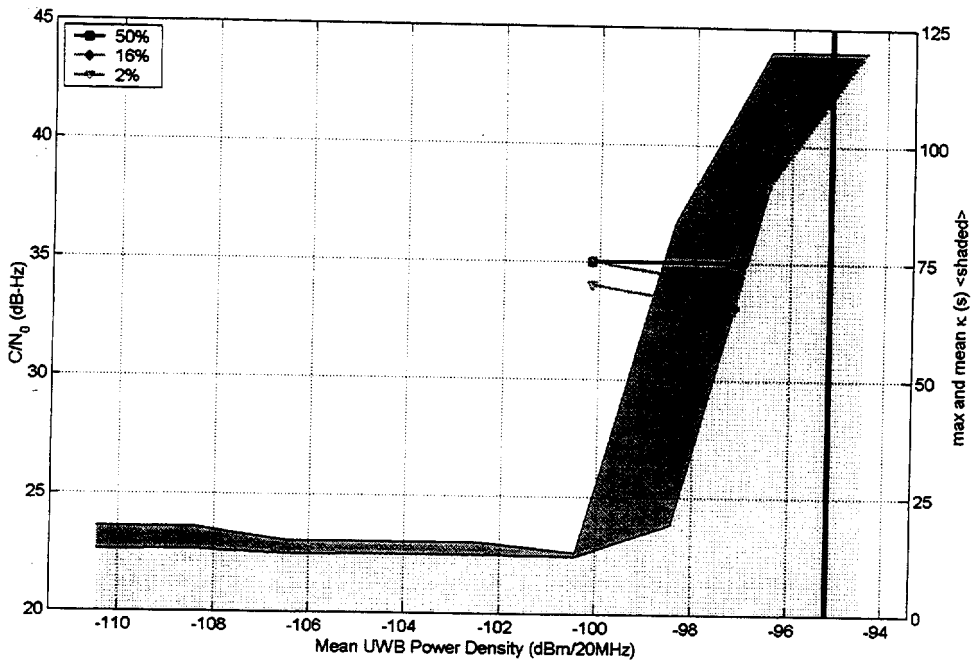

Figure B.2.26. Measured GPS parameters (Rx 4) as a function of 20-MHz PRF, 2% RRD, non-gated UWB interference.

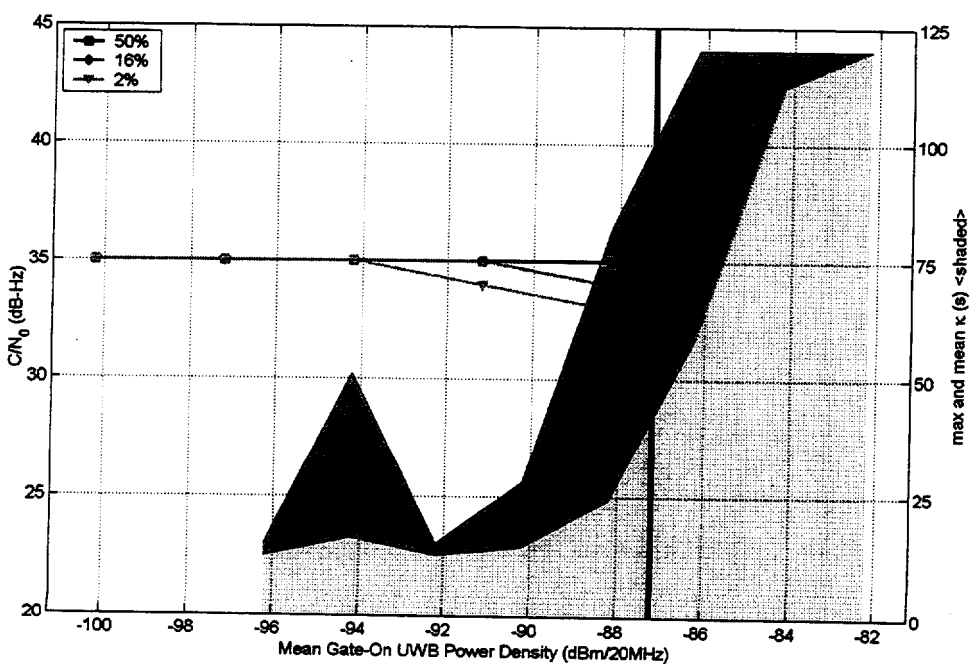

Figure B.2.27. Measured GPS parameters (Rx 4) as a function of 20-MHz PRF, 2% RRD, gated (20% duty cycle) UWB interference.

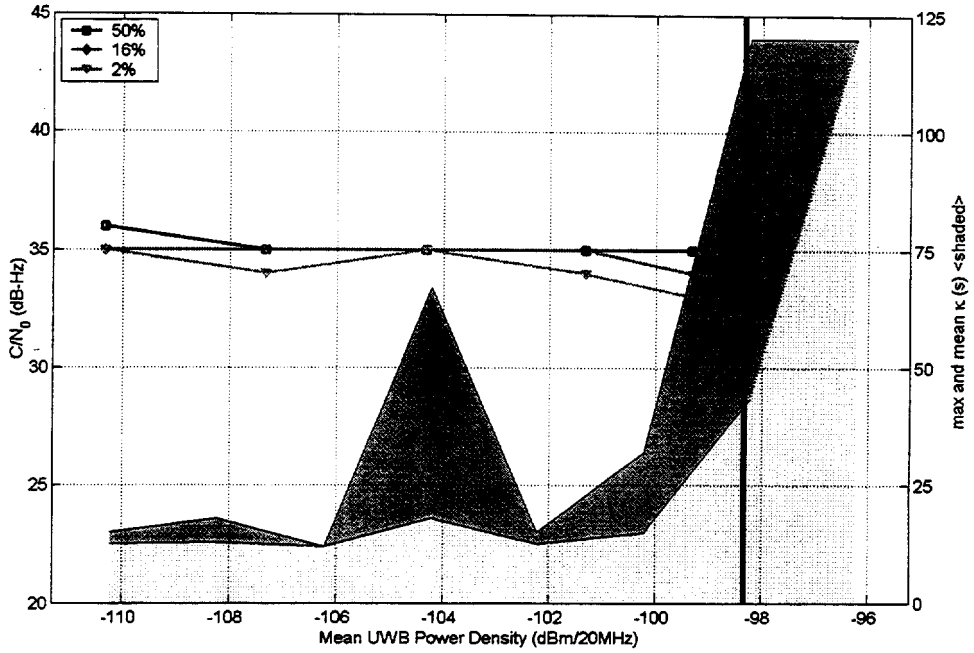

Figure B.2.28. Measured GPS parameters (Rx 4) as a function of 5-MHz PRF, 2% RRD, non-gated UWB interference.

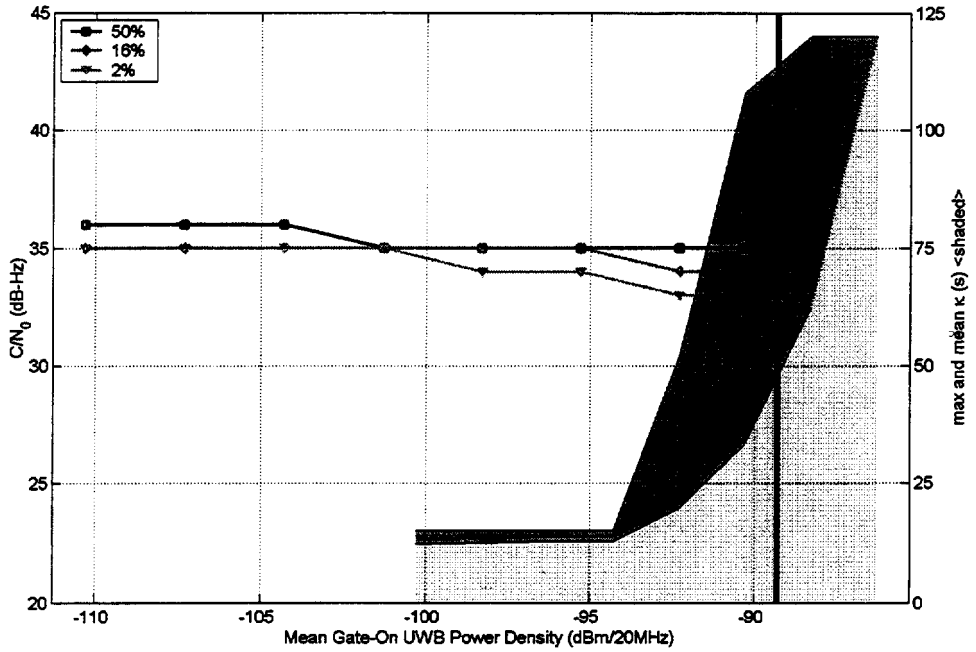

Figure B.2.29. Measured GPS parameters (Rx 4) as a function of 5-MHz PRF, 2% RRD, gated (20% duty cycle) UWB interference.

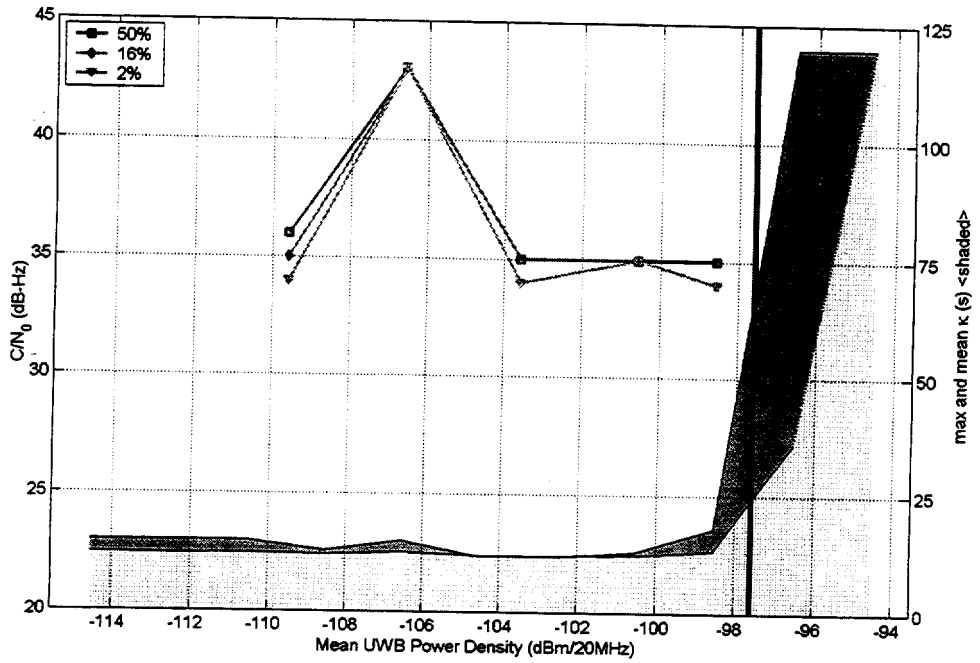

Figure B.2.30. Measured GPS parameters (Rx 4) as a function of 1-MHz PRF, 2% RRD, non-gated UWB interference.

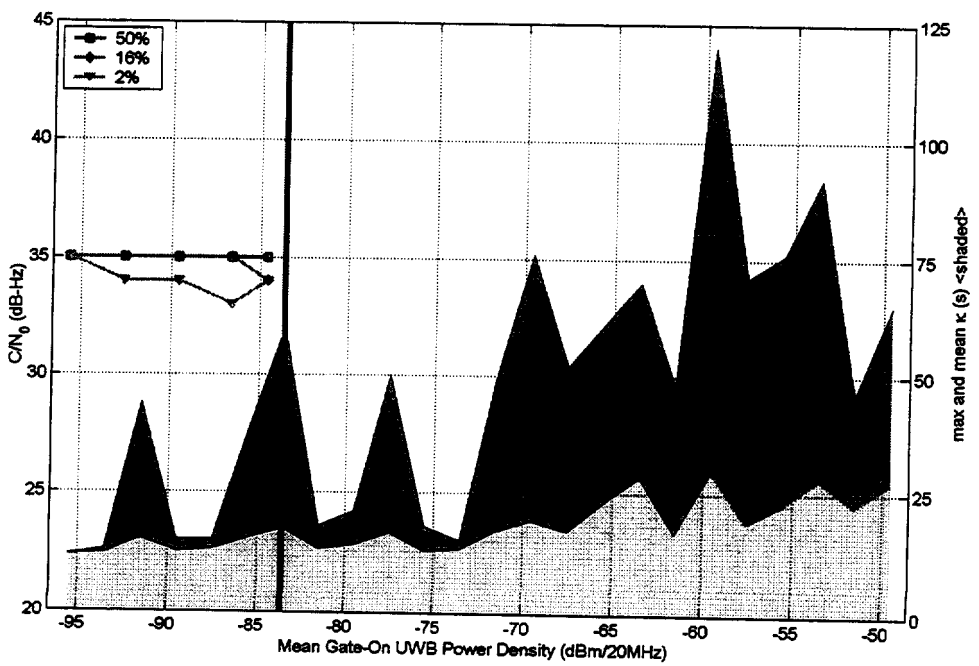

Figure B.2.31. Measured GPS parameters (Rx 4) as a function of 1-MHz PRF, 2% RRD, gated (20% duty cycle) UWB interference.

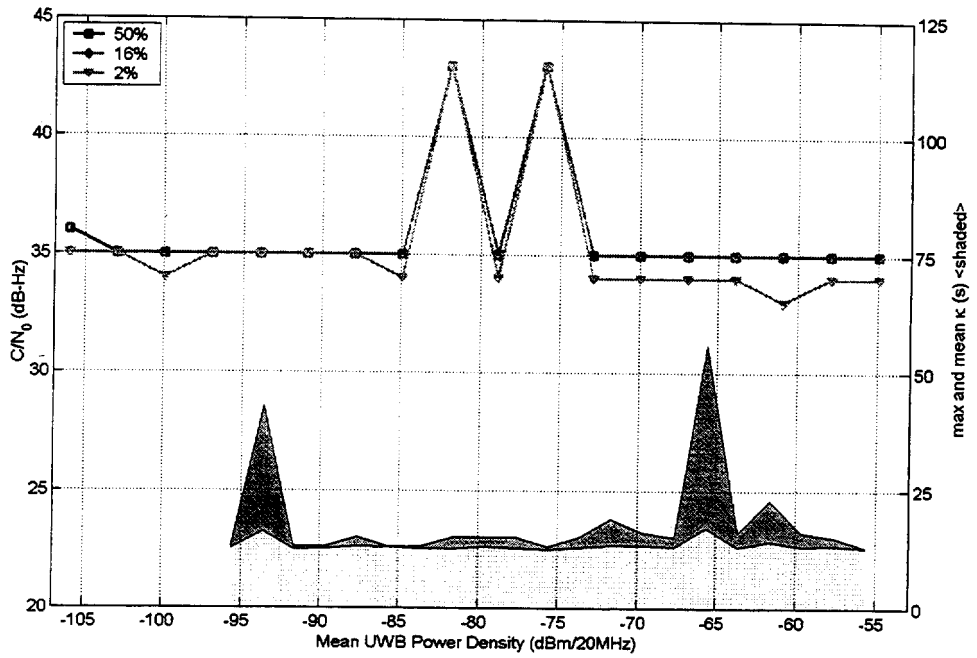

Figure B.2.32. Measured GPS parameters (Rx 4) as a function of 0.1-MHz PRF, 2% RRD, non-gated UWB interference.

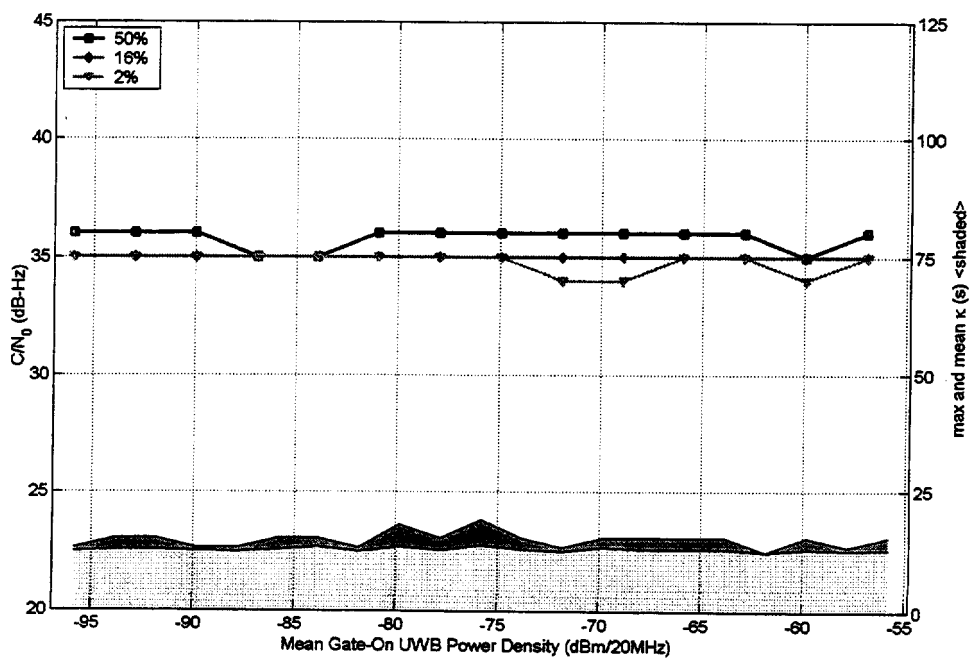

Figure B.2.33. Measured GPS parameters (Rx 4) as a function of 0.1-MHz PRF, 2% RRD, gated (20% duty cycle) UWB interference.