Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Amendment of Parts 2 and 25 to Implement	)	IB Docket No. 99-67
the Global Mobile Personal Communications	)	
by Satellite (GMPCS) Memorandum	)	
of Understanding and Arrangements	)	
	)	
Petition of the National Telecommunications and	)	RM No. 9165
Information Administration to Amend Part 25 of the	)	
Commission's Rules to Establish Emissions Limits for	)	
Mobile and Portable Earth Stations Operating in the	)	
1610-1660.5 MHz Band	)	

NOTICE OF PROPOSED RULE MAKING

Adopted: February 25, 1999 **Released: March 5, 1999**

LSC Comments on Protection for GPS/GLONASS Radionavigation Systems

The United States government has invested over $13 billion dollars in implementing GPS for military and civilian users world wide. The system has been in operation since 1978 and fully operational since 1993. The proposed GMPCS out of band emission limits have the potential to invalidate the incumbent GPS system by randomly denying navigation signals to current incumbent users.

The analysis in these proceedings and past proceedings[1] has not addressed the problem of GMPCS out of band power aggregation due to multiple handsets. In the presence of multiple GMPCS handsets, GPS jam out range increases significantly. Compared with the exclusion range for a single GMPCS user, exclusion ranges would be 1.41 times larger for two GMPCS users and for 10 GMPCS users; 3.16 time further. No mechanism for preventing handset power aggregation has been identified and it calls into question whether the RTCA and NTIA recommendations really offer adequate protection even for aviation users.

Under the proposed rules, if a typical GPS receiver comes within 925 feet (~1/5 of a mile) of 10 GMPCS users, it will experience more than 3dB of sensitivity loss. This is enough loss to prevent GPS signal acquisition and thus positioning for many receivers currently in use.

Additionally, we note that it was not until these specific proceedings (99-37) that protection of precision approach aircraft users AND ONLY precision approach aircraft users was contemplated. What of the hundreds of thousands if not millions of incumbent non-aviation GPS users currently benefiting from the GPS system? Do they not deserve incumbent status and attendant protections? Should they simply throw away their

[1] GEN Docket No. 98-68 1998 Biennial Regulatory Review --Amendment of Parts 2, 25 and 68 of the Commission's Rules to Further Streamline the Equipment Authorization Process for Radio Frequency Equipment, Modify the Equipment Authorization Process for Telephone Terminal Equipment, Implement Mutual Recognition Agreements and Begin Implementation of the Global Mobile Personal Communications by Satellite

equipment to make way for GMPCS, a service not even contemplated when GPS was first deployed? Does the FCC propose to ignore the Vice President's published policy on GPS?

> *"We will continue to do everything we can to protect these GPS signals and to promote GPS for commercial, public safety, and national security purposes"*[2]

If the economic benefits of GMPCS outweigh the economic benefits of a $13 billion incumbent system, the GMPCS community needs to reimburse GPS/GLONASS incumbents for loss of utility. A precedent for this was set in spectrum refarming for PCS where POFS users were wholly reimbursed for loss of spectrum. Incumbent GPS users need protections similar to those given to POFS[3] users in the 1850-1990 MHz PCS bands.

Returning to the RTCA recommendation and NTIA recommendations for protection of precision approach aircraft, they are based on GPS receiver antenna gains being less than -10 dBiC in the direction of a single GMPCS transmitter. While this may be a reasonable assumption for aircraft on final approach; in the majority of radionavigation applications currently extant, this is not the case; antenna gains of + 3dBi or higher are not unreasonable given the need to receive GPS/GLONASS signals from a plurality of directions to obtain a navigation solution. We would urge the commission to consider the full spectrum of existing safety of life and radionavigation applications rather than limit

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(GMPCS) Arrangements NOTICE OF PROPOSED RULE MAKING FCC 98-92
Adopted: May 14, 1998

[2] from Vice President's announcement on GPS enhancements released March 30, 1998. Available at http://www.navcen.uscg.mil/gps/issues/gpspressreleases.htm

itself to a single "final approach" application before making a final ruling. Otherwise, current GPS/GLONASS users will be at risk of sudden and unexpected interruption in many safety of life applications. Significant economic impact will also accrue as current GPS users stand around baffled as to why their GPS set "doesn't work".

Borrowing from the NPRM we continue to recommend an additional 13 dB of protection.

Item 5a in Appendix A of the NPRM would read:

(a) *Limits on Emissions Below 1605 MHz.*

(1) The e.i.r.p. density of emissions from mobile earth terminals placed in service prior to January 1, 2002 with assigned frequencies between 1610 MHz and 1660.5 MHz shall not exceed -83 dBW/MHz, averaged over any 20 ms interval, in the band 1559-1580.42 MHz. The e.i.r.p. of discrete spurious emissions of less than 700 Hz bandwidth generated by such terminals shall not exceed -93 dBW, averaged over 20 ms, in the band 1559-1585.42 MHz.

(2) The e.i.r.p. density of emissions from mobile earth terminals placed in service prior to January 1, 2002 with assigned frequencies between 1610 MHz and 1626.5 MHz shall not exceed -70 dBW/MHz, averaged over 20 ms, in the band 1580.42-1605 MHz. The e.i.r.p. of discrete spurious emissions of less than 700 Hz bandwidth generated by such terminals shall not exceed -80 dBW, averaged over 20 ms, in the band 1585.42-1605 MHz

(3) The e.i.r.p. density of emissions from mobile earth terminals placed in service after January 1, 2002 with assigned frequencies between 1610 MHz and 1660.5 MHz shall not exceed -83 dBW/MHz, averaged over 20 ms, in the 1559-1605 MHz band. The e.i.r.p. of spurious emissions of less than 700 Hz bandwidth from such terminals shall not exceed -93 dBW, averaged over 20 ms, in the 1559-1605 MHz band.

(4) As of January 1, 2005 and from then on, the e.i.r.p. density of emissions from mobile Earth terminals placed in service prior to January 1, 2002 with assigned frequencies between 1610 MHz and 1660.5 MHz shall not exceed -83 dBW/MHz, averaged over 20 ms, in the 1559-1605 MHz band, and the e.i.r.p. of spurious emissions of less than 700 Hz bandwidth from such terminals shall not exceed -93 dBW, averaged over 20 ms, in that band.

[3] Private Operational Fixed Services POFS is a point to point fixed microwave service

We would also note that both GPS and GLONASS use Right Hand Circular Polarization (RHCP) antennas. These antennas generally afford significant rejection of Left Hand Circular Polarized (LHCP) signals[4]. Depending on axial ratios, there is at least 3 dB of rejection against LHCP and greater than 10dB of rejection is the norm. If GMPCS uses LHCP, less stringent emission masks are needed; coexistence becomes much easier to accomplish. Given the space based nature of GMPCS and MSS in general; there may be advantages in using circular polarized antenna's as opposed to linear polarizations commonly associated with ground mobile systems. We strongly encourage examination of this option and comment from the GMPCS community since it affords the best hope for coexistence between GMPCS and GPS/GLONASS systems on an economical basis.

[4] For example, see figure 4 in this document.

Justification

It is not clear to us that protection should be afforded only to radionavigation users having safety of life considerations. The large number of incumbent GPS users all deserve protection from GMPCS interference as was originally intended in the WRC-92 and General Docket 98-68. The United States Vice President's policy statement on GPS (March 30, 1998) states:

> *"We will continue to do everything we can to protect these GPS signals and to promote GPS for commercial, public safety, and national security purposes"*

These proceedings certainly belie the Vice President's statements, stating that only airborne precision approach systems deserve protection. Interestingly, no protection is afforded the ground portions of these very same systems (e.g. SCAT-1 systems already deployed). Nonetheless, we can find several incumbent, non-aviation applications having safety of life implications.

Example Safety of Life Applications That are Not Airborne

Currently, Police, Fire and Medical Rescue services all make extensive use of GPS to provide dispatch, rendezvous, and monitoring functions with safety of life implications. Disruptions in service to these users could lead to loss of life. Train switching and control is accomplished using GPS. Tectonic plate stress monitoring, dam stress/fracture monitoring and pipeline monitoring applications are all using GPS in an effort to provide early warning of impending disaster. The ONSTAR service, which includes emergency road services, uses GPS as it's positioning sensor. Utilities companies routinely use GPS for downed line locating and dispatch. GPS plays a significant role in minefield clearing, providing a reliable grid to avoid missed spots. There are over 600,000 child abduction attempts each year; GPS is being used to locate some of these children using a kidfinder concept combining cellular telephones with GPS. Again, these are all incumbent, extant GPS applications with strong safety of life implications.

Also, the FCC made a final ruling on Enhanced 911 (E911) services in:

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Revision of the Commission's Rules  )   CC Docket No. 94-102
To Ensure Compatibility with        )        RM-8143
Enhanced 911 Emergency Calling Systems)

                  Memorandum Opinion and Order

Adopted:  December 1, 1997      Released:  December 23, 1997
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requiring:

> (e) Phase II Enhanced 911 Services As of October 1, 2001, licensees subject to this section must provide to the designated Public Safety Answering Point the location of all 911 calls by longitude and latitude such that the accuracy for all calls is 125 meters or less using a Root Mean Square (RMS) methodology.

GPS is one of the leading candidates for providing this required positioning capability to cellular telephony users. Systems have been demonstrated by SNAPTRACK in conjunction with Ericson.

In reply comments to general docket 98-68, AMSC stated:

> *"It is not fair to these MSS operators to perpetually reassess the necessary limits on MSS emissions with the arrival of each successive GPS marketing plan"*

Perhaps this should be turned around to:

> *"It is not fair to these current GPS users to perpetually reassess the necessary tolerance to MSS emissions with the arrival of each successive MSS frequency plan"*

The core question to be asked regarding coexistence in these proceedings should be: "Can proposed GMPCS emission limits lead to disruption of radionavigation services and if so, what are more appropriate limits?" We would like to suggest an engineering approach. To address this question we need to look at GPS receiver sensitivities to interference. This author has over 20 years GPS experience in systems engineering roles and encourages the GMPCS community to comment on the following with engineering arguments rather than unsupported blanket denials.

Wideband Emissions Limits Analysis

GPS receivers determine location by measuring pseudorange to 4 (or more) GPS satellites to solve for position in x,y,z, and time. At the heart of the pseudorange measurement process are two tracking loops; the Phase Locked Loop (PLL) and the Delay Locked Loop (DLL). The PLL tracks GPS signal carrier phase and thus Doppler to a given satellite. It is also required to read 50 bps data telling the user where the satellite is. The DLL tracks GPS signal code phase and thus pseudorange to a given satellite.

The PLL provides exquisitely accurate measurements of any changes in pseudorange but is unable to observe pseudorange directly because the L1carrier (1575.42MHz) is ambiguous every 19 cm (1 wavelength). Just about every GPS receiver on the market uses this information to aid the DLL in what is commonly referred to as carrier aided code tracking. If the PLL looses lock on a given satellite, full accuracy tracking is lost[5]. Thus, PLL tracking threshold is the defining point for loss of lock to a given satellite.

[5] Frequency Locked Loops can extend threshold tracking performance an additional 3 to 5 dB but during this mode of operation, navigation accuracy degrades and 50 bps data is not easily read.

Equation 1 shows PLL tracking jitter as a function of C/No for a Costas Loop of the type commonly found in GPS receivers[6].

$$\sigma_{PLL}(\text{degrees}) = \sqrt{\frac{1}{C/No}\left(1 + \frac{0.5}{C/No\ T}\right) B_l k}\ \frac{180}{\pi} \qquad \textbf{(Equation 1)}$$

where:

$C/No = \text{Carrier to Noise Spectral Density Ratio (numeric)}$

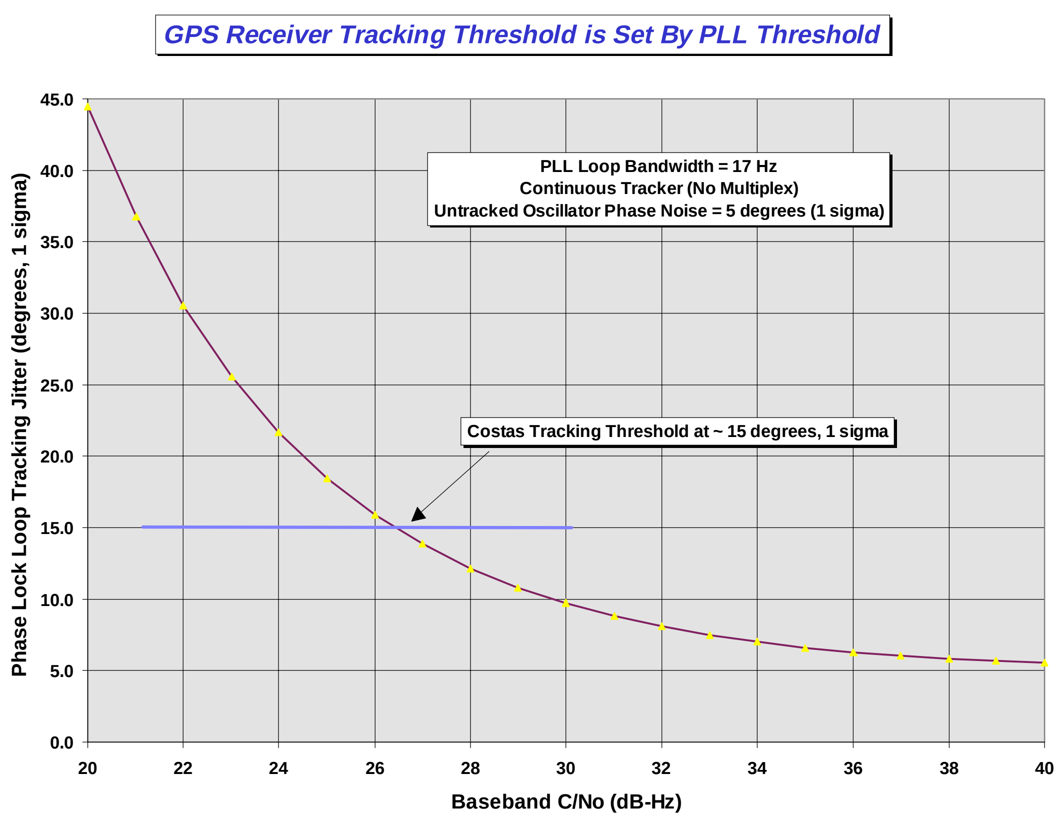
$B_l = \text{Loop Bandwidth (Hz)}$

$k = \text{Multiplex Factor (Number of SV's Tracked per Channel}$

$T = \text{Predetection Integration Time (seconds)}$

Figure 1 plots this equation using a typical GPS PLL loop bandwidth[7] of 17 Hz and a predetection integration time of 20 msec.

Figure 1: PLL Jitter as a Function of C/No



[6] Other types of discriminators such as sign(I)*Q and ATAN2(Q,I) show similar performance.
[7] Loop bandwidth requirements are set by user equipment dynamics.

From this chart we can infer that a continuous tracking GPS receiver has reached its tracking threshold when baseband C/No reaches 26 dB-Hz. This corresponds to a tracking jitter of 15^o (1σ); much more and the PLL discriminator produces too many ambiguous phase error measurements and the tracking loop looses lock. Table 1 shows baseband C/No and associated tracking and acquisition margins for a low elevation satellite for three types of receiver: a multichannel continuous receiver, a 4 SV(Satellite Vehicle)[8] Multiplex(MUX) receiver, and an 8 SV MUX receiver.

In Table 1 we've assumed a 1.5 dB Noise Figure typical of off the shelf active antennas. The 2 dB implementation loss is characteristic receivers using one bit A/D converters. Given that most GPS satellites are at low elevation angles[9], a -4 dBiC antenna gain has been used in computing baseband C/No. This makes allowances for user tilt and antenna gain falloffs associated with reception at lower elevation angles. With these assumptions; baseband C/No is at 36.4 dB-Hz when L1 C/A signal strength is at -130 dBm as specified in ICD-GPS-200C (25 September 1997).

[8] An SV is a GPS satellite.
[9] 50% of GPS satellites are found at elevations between 0^o and 30^o above the horizon. GPS receivers typically limit themselves to using only satellites above 5^o because of undesirable signal propagation effects at lower elevation angles.

Table 1: L1 C/A GPS Receiver Margin Analysis

Number of SV's Tracked per Channel (Multiplex Factor):	**1.00**	**4.00**	**8.00**
Antenna Temperature (K):	300.00	300.00	300.00
GPS Receiver Noise Figure (dB @290K):	1.50	1.50	1.50
GPS Receiver Noise Temperature (K):	119.64	119.64	119.64
System Noise Temperature (K):	419.64	419.64	419.64
Total Thermal Noise Power (dBm/Hz):	-172.37	-172.37	-172.37
GPS Signal Power (dBm):	-130.00	-130.00	-130.00
Antenna Gain (dBiC):	-4.00	-4.00	-4.00
Receiver Implementation Loss (dB):	2.00	2.00	2.00
Received Baseband C/No(dB-Hz):	36.37	36.37	36.37
Tracking Threshold (dB-Hz):	26.00	32.02	35.03
Tracking Margin (dB):	**10.37**	**4.35**	**1.34**
Acquisition Threshold (dB-Hz):	30.00	36.02	39.03
Acquisition Margin (dB):	**6.37**	**0.35**	**-2.66**

In the case of a continuous tracking multichannel receiver we see a tracking threshold margin of 10.4 dB and an acquisition margin[10] of 6.4 dB. When we consider multiplexing receivers, margins drop by 10 $\log_{10}(4)$ = 6 dB for the 4 channel multiplex receiver and 10 $\log_{10}(8)$ = 9 dB for the 8 channel multiplex receiver. It is unlikely the 8 SV MUX receiver could acquire under these conditions and would have to use higher elevation angle satellites with attendant degradation in navigation accuracy because of worsened HDOP[11] (Horizontal Dilution Of Precision) and PDOP (Position Dilution Of Precision). From

[10] RTCA recommendations place acquisition threshold 6 dB above tracking threshold but our experience is that 4 dB is adequate.

Table I we can infer that GPS receivers do not necessarily operate with a great deal of link margin; particularly multiplex receivers[12]. Relatively small receiver sensitivity losses can lead to a loss of lock and subsequent loss of positioning. In support of this, we note that the RTCA recommendation allows for only 1.5 dB of sensitivity loss.

We now come to the question of how much GMPCS out of band emissions desensitize GPS receivers. Table 2 shows thermal noise power spectral density coming out of the GPS receiver preamplifier referenced to the input assuming a 1.5 dB Noise Figure and a 300K antenna temperature characteristic of the "omnidirectional" GPS antennas used in typical user equipment.

Table 2: Post Amplification Thermal Noise Power (referenced to input)

Antenna Temperature (K):	300
GPS Receiver Noise Figure (dB @290K):	1.5
GPS Receiver Noise Temperature (K):	119.6358879
System Noise Temperature (K):	419.6358879
Total Thermal Noise Power (dBm/MHz):	-112.3724829

Assuming free space propagation[13] from a single GMPCS transmitter to the victim GPS receiver we obtain the results of figure 2 under the RTCA assumption of -10 dBiC GPS gain in the direction of the GMPCS transmitter. Desensitization is computed as:

[11] Horizontal location (east/north) is derived primarily from low elevation satellites while vertical (up) positioning is derived primarily from higher elevation angle satellites.

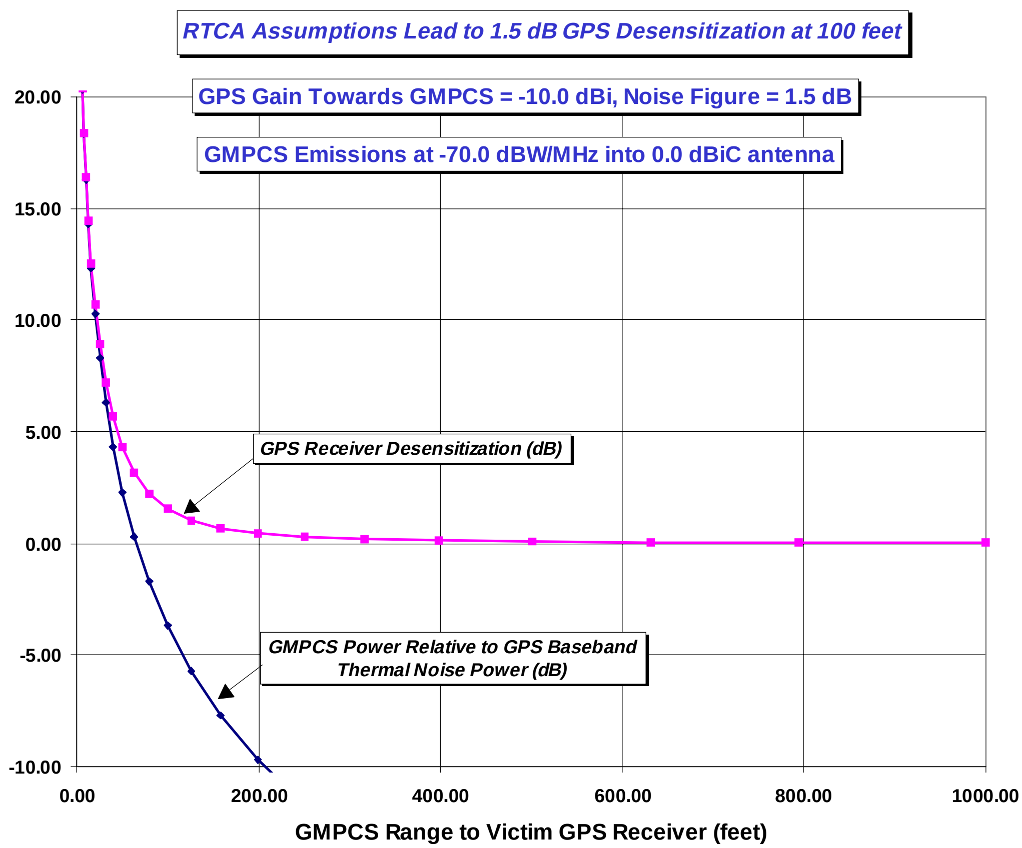
[12] To see a specification sheet showing receiver tracking threshold of 34 dB-Hz; look at http://www.marconi.ca/Docs/CMC/Aerospace/cma3112.html

[13] At L1 frequency (1575.42 MHz), free space path loss is PL (dB) = 96.4 + 20 Log_{10} R where R is in km

$$GPS\ Desensitization(dB) = 10\log_{10}\left(\frac{N_{thermal} + I_{GMPCS}}{N_{thermal}}\right) = 10\log_{10}\left(1 + \frac{I_{GMPCS}}{N_{thermal}}\right) \quad \textbf{\textit{(Equation 2)}}$$

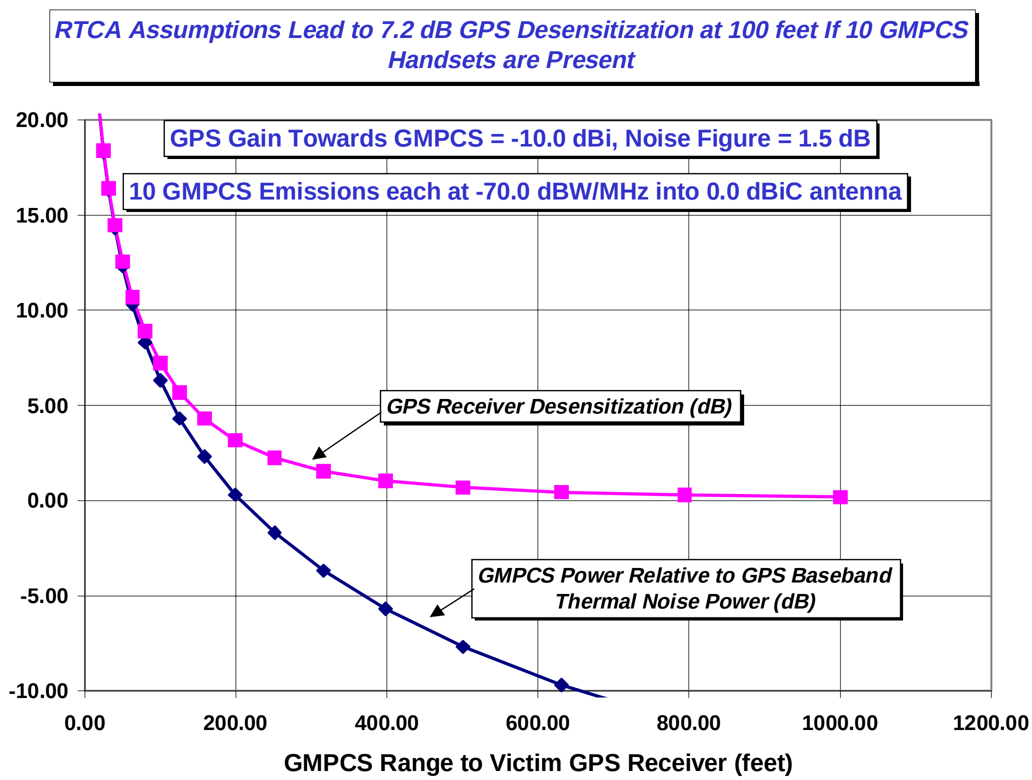
Close examination shows 1.5 dB of desensitization at 100 feet which seems reasonable.

Figure 2: RTCA Assumptions Lead to 1.5 dB Desensitization at 100 feet



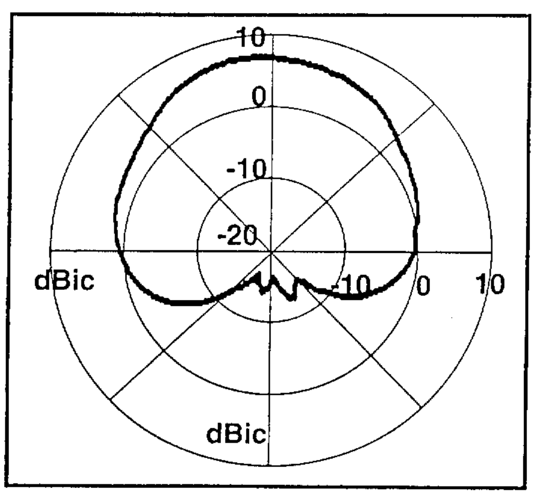
Now consider the possibility of 10 GMPCS handsets present, perhaps at an airport. In this case, the RTCA assumptions lead to a 7.2 dB sensitivity loss at 100 feet as is shown in Figure 3. This is enough to knock out several types of aviation receiver currently in use and, at a most critical flight phase, namely landing. In their reply comments to General Docket 98-68 Raytheon points out that the WAAS reference receiver at the Billings Flight Service Station is easily within 71 meters of locations where GMPCS handsets could be used. Hope nobody wants to land there in bad weather.

Figure 3: RTCA Assumptions & 10 Handsets Lead to 7.2 dB Desensitization at 100'

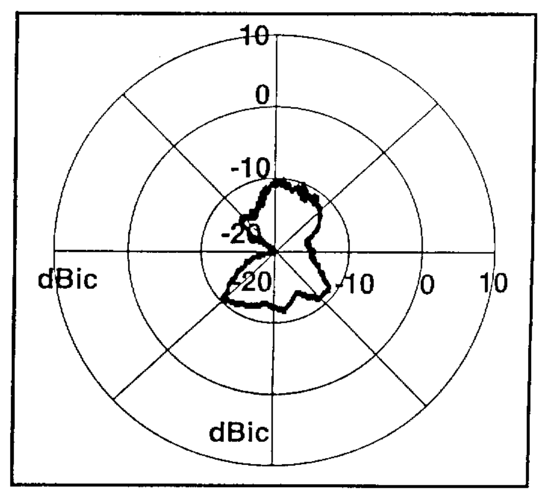


Now consider a more typical antenna for ground mobile GPS applications. Figure 4 shows RHCP & LHCP elevation cuts for a typical L1 only GPS antenna. It has 0 dBiC (RHCP) gain at the horizon and about +3 dBiC (RHCP) gain at 30° elevation. Using a +3 dBiC (RHCP) gain toward the GMPCS transmitter to account for roll, we now obtain the results of Figure 5. Now we see almost 10dB of GPS receiver desensitization at 100 feet. The results of Table 1, show that just about every class of GPS receiver would be in serious trouble with this level of desensitization. This would be particularly true if there are other propagation impairments such as foliage attenuation and/or building penetration losses.

<u>Figure 4: Typical GPS Antenna Gain Pattern (NovAtel Model 501)</u>

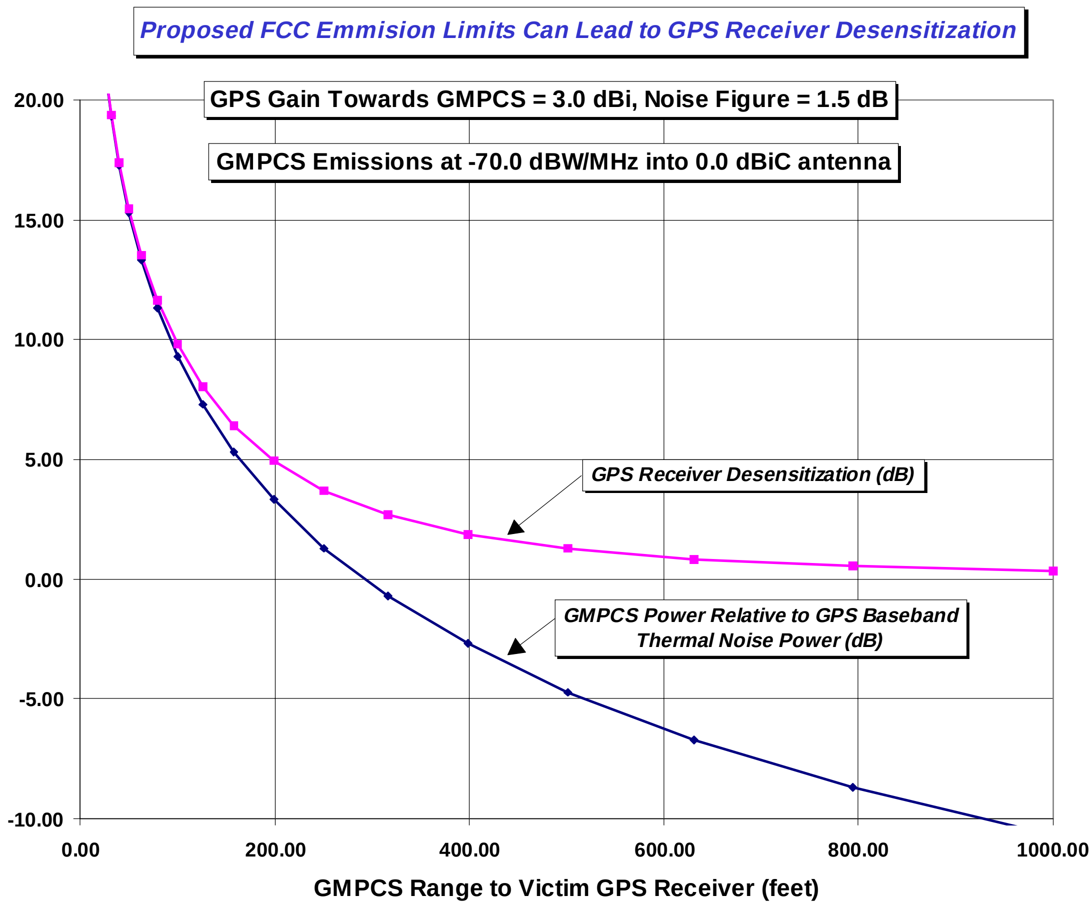


GPS Antenna Elevation Gain Pattern
Right Hand Circular Polarization



GPS Antenna Elevation Gain Pattern
Left Hand Circular Polarization

Figure 5: Under +3dBiC Assumption, GMPCS causes 9.8 dB of GPS Receiver Desensitization at 100 feet

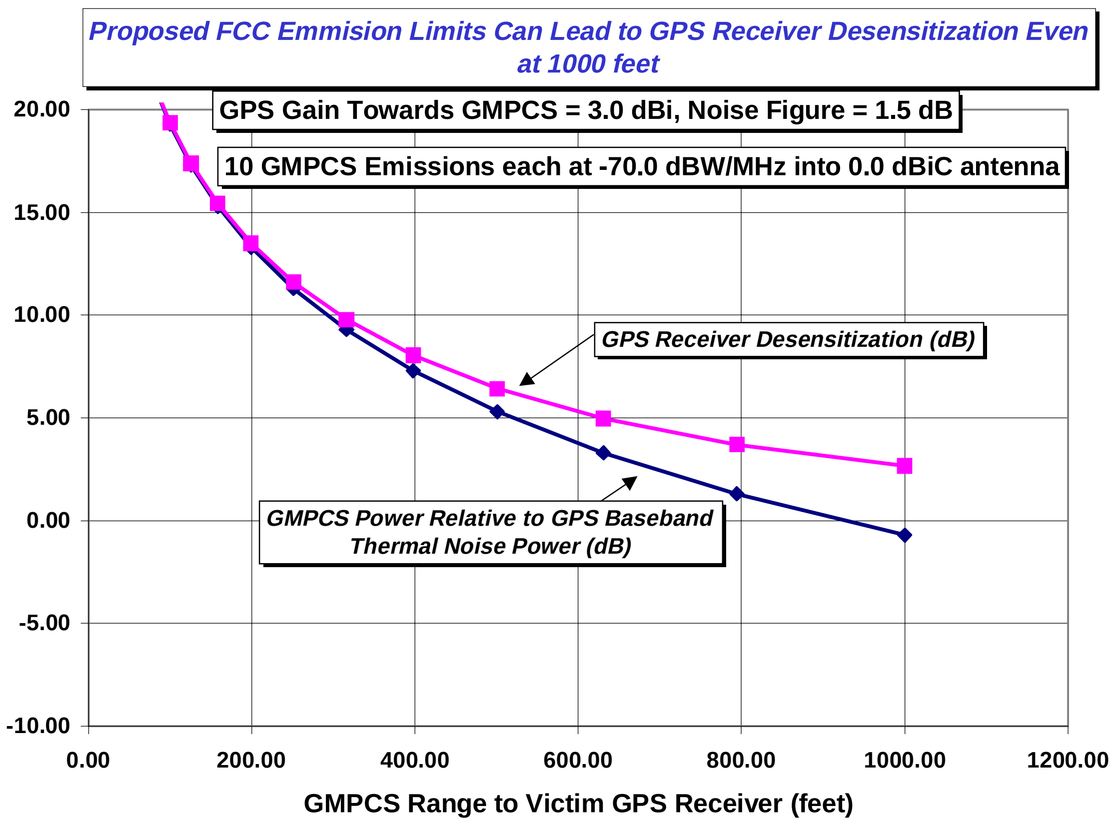


We argue that the use of a 100 foot range is even more appropriate in ground mobile applications where there is a high probability that GMPCS earth terminals could get within 100 feet of a GPS receiver. Imagine the police officer who calls for backup and expects GPS to automatically provide a position fix[14] but there is a GMPCS user across the street jamming him out.

[14] In the military arena, Combat Survivor / Evader Locator (CSEL) provides this capability in the form of a 28 oz. unit that combines a UHF radio with a GPS to automatically report position. Police will likely carry similar units in the near future.

If we now consider the possibility of multiple handsets, we obtain the results of figure 6. Most receivers on the market are completely jammed out at 400 feet and at 1000 feet many types would be unable to acquire and provide positioning data.

Figure 6:, 10 GMPCS Handsets cause 19.4 dB of GPS Receiver Desensitization at 100'



Again using free space propagation models, Figure 7 shows allowable single emitter GMPCS emission limits as a function of range to maintain desensitization protection levels of 1, 1.5 and 3 dB. Figure 8 shows comparable results for the 10 emitter case.

Figure 7: Allowable GMPCS Emission Limits To Provide Specified Level of Protection

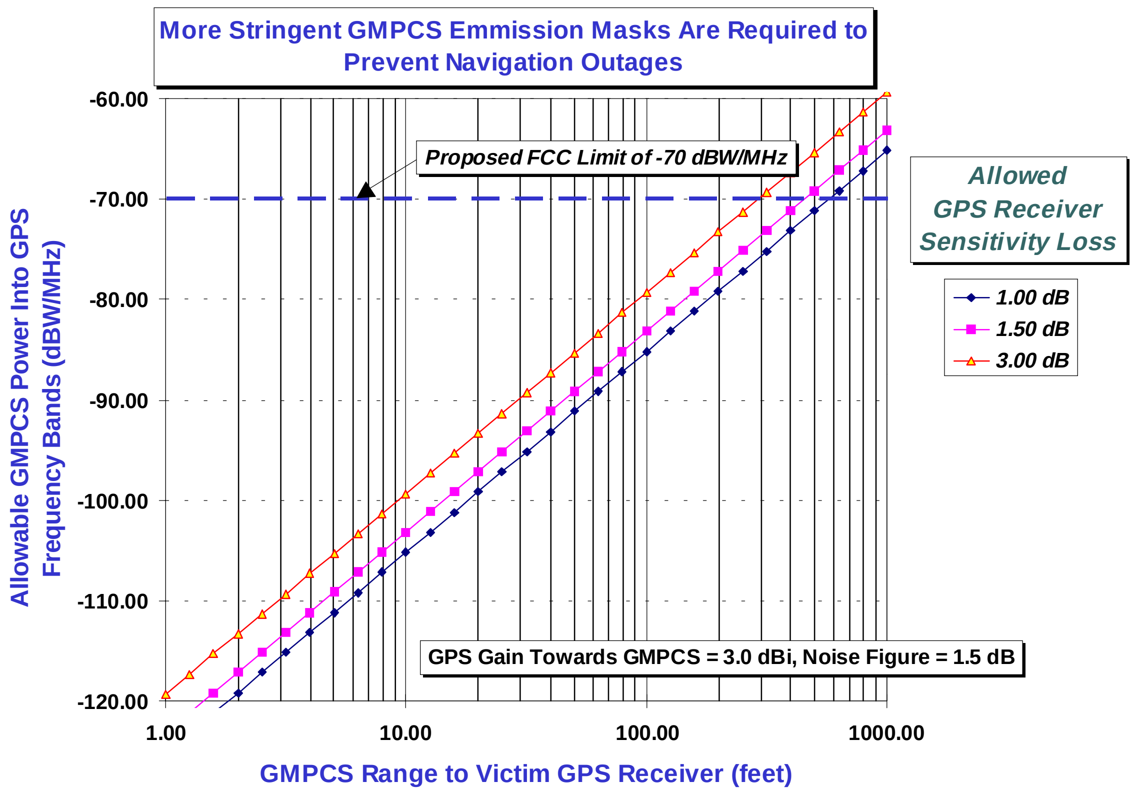
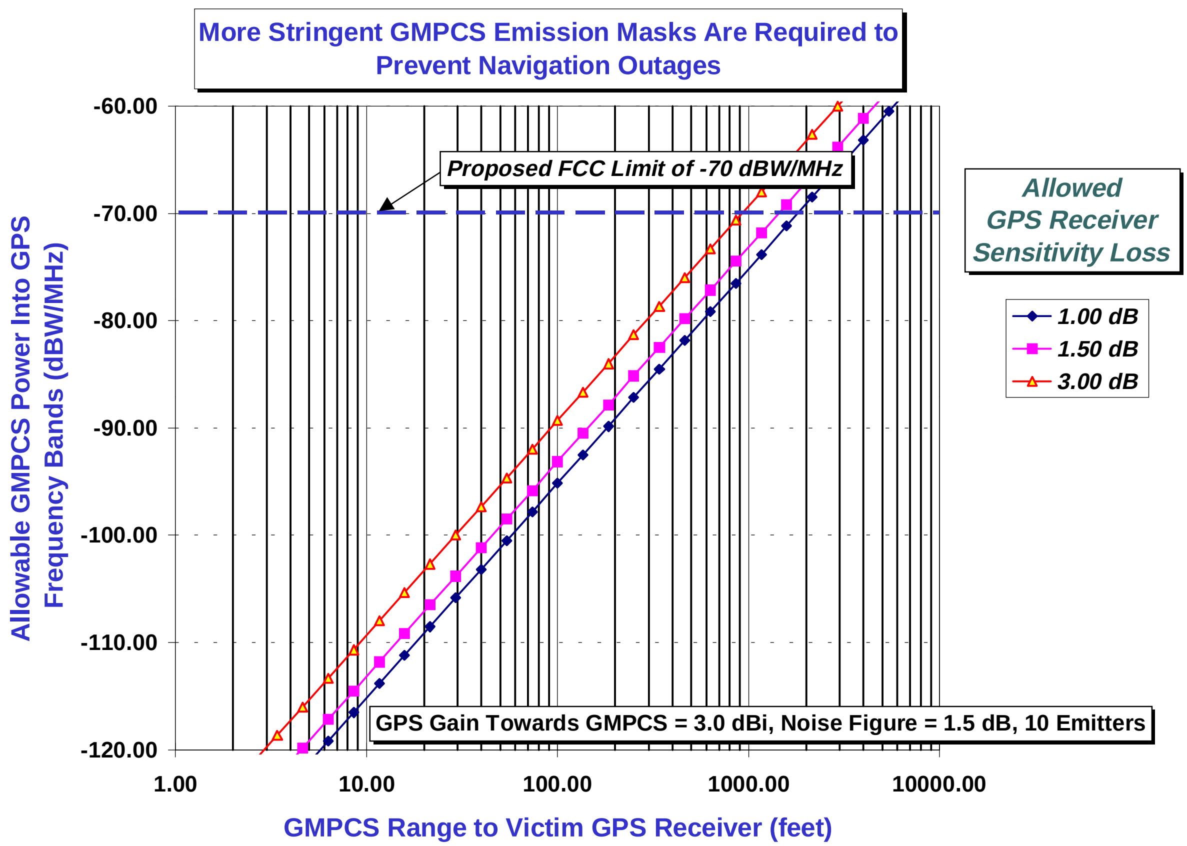


Figure 8: Allowable GMPCS Emission Limits To Provide Specified Level of Protection Given 10 Emitters



Working on the Vice President's premise that all GPS applications deserve protection, we see that GMPCS out of band emission limits should be held to at most -83 dBW/MHz EIRP for radionavigation systems to provide protection from a single GMPCS emitter. If power aggregation from multiple GMPCS emitters is considered, even more stringent specifications might be needed.

Narrowband Emissions Limits Analysis

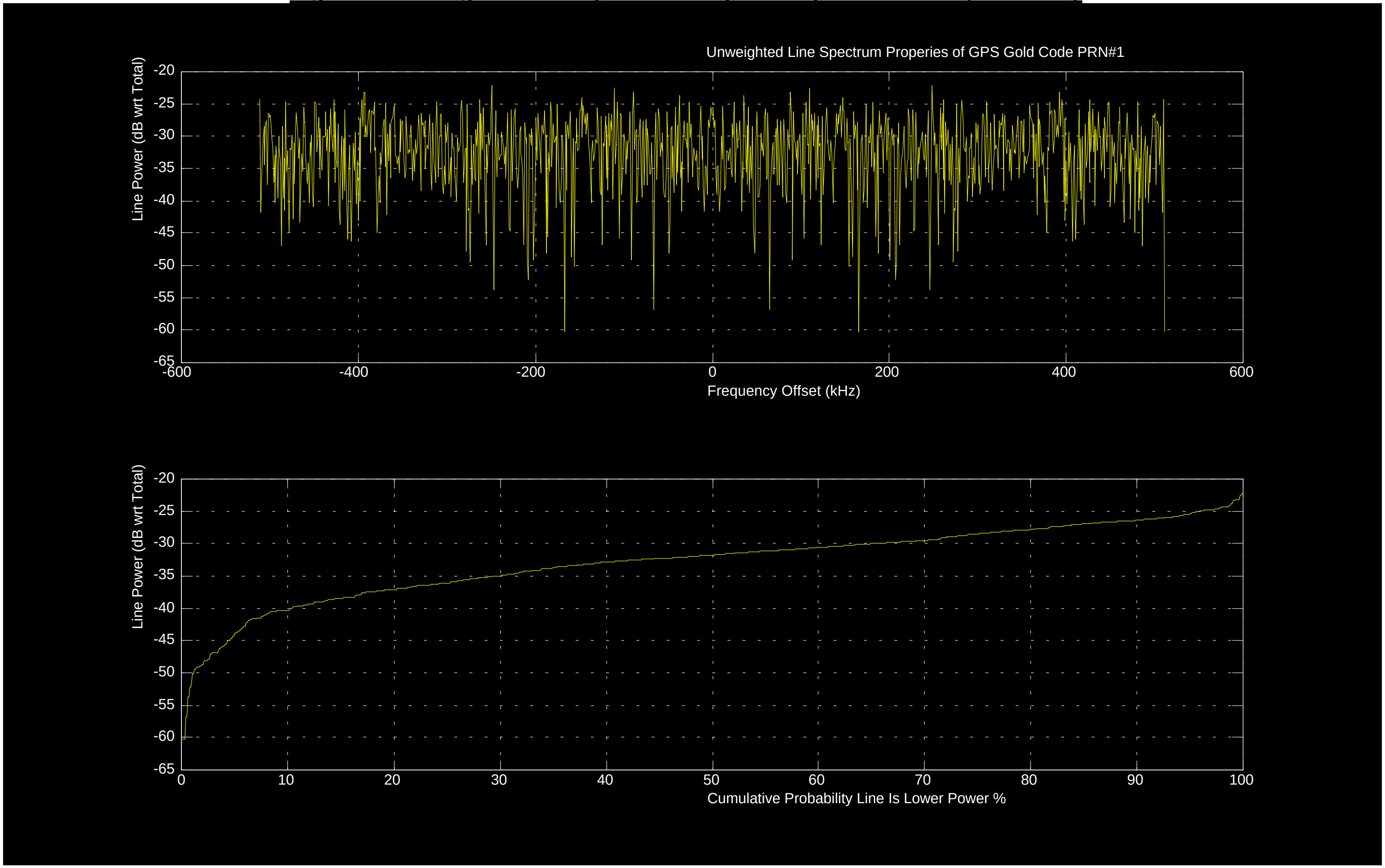
Regarding narrowband emission limits, the NPRM is not specific on narrowband GMPCS emission bandwidths; it simply states a measurement bandwidth of 700 Hz. Narrowband GMPCS out of band emissions may actually be CW if they are synthesizer spurs or they may be modulation artifacts having somewhat wider bandwidths. There may be multiple spurs occurring within the GPS/GLONASS frequency band.

CW interference can be particularly damaging for C/A code receivers because of the C/A code's line spectrum structure. Military P(Y) receivers use a long period code and have no particular susceptibility towards CW jamming.

The C/A code has a line spectrum structure because of its short length (1023 chips). Figure 9 shows the line spectrum properties of C/A code PRN#1 which is typical of all of the codes[15]. A C/A code period of 1 msec results in lines spaced 1 kHz apart. While most of the line components are small with respect to (wrt) the total GPS signal energy, there is

[15] GPS is a Code Division Multiple Access (CDMA) system with each SV broadcasting a distinct code. GPS and WAAS C/A codes are all members of a single Gold code family.

Figure 9: Unweighted Line Spectrum Properties of GPS PRN#1 (C/A Code)



a small fraction of powerful line components. Figure 6 shows 96% of the lines are below -25 dB wrt total energy and 66% are below -30 dB wrt total energy.

The significance of these lines is that if a C/A code receiver gets hit by a CW jammer at a big line's frequency offset, the GPS receiver doesn't show full processing gain against the interfering source. Instead, the jammer is attenuated only by the magnitude of the line plus attenuation due to baseband filtering prior to the PLL discriminator[16]. The PLL may then lock onto the resultant baseband CW signal if it is strong enough but in well designed GPS receivers appropriate tests make sure the set is truly locked onto a GPS signal. Nonetheless, jamming energy can disrupt tracking and lead to a loss of navigation.

Baseband filtering significantly alters CW jammer sensitivities by providing additional attenuation beyond that provided by the C/A code. Predetection integration times of 20 msec are typical in continuous tracking GPS receivers. This corresponds to a predetection equivalent noise bandwidth of 1/(.020 sec)=50 Hz. Four SV MUX receivers typically use a 20 msec / 4 = 5 msec Predetection Integration Time (PIT) and 8 SV MUX receivers use a 20 msec / 8 = 2.5 msec PIT. The specific filter response is given by:

$$H(f) = \frac{\sin(\pi f_e T)}{\pi f_e T}$$ where T is predetection integration time & f_e is frequency offset

[16] Often referred to as arm filters.

Figure 10 plots this filter's power response. A strong line response showing up at 100 Hz frequency offset from center frequency would be strongly attenuated if we are using a 20 msec PIT but would only be attenuated by 0.9 dB if we use a 2.5 msec PIT.

Figure 11 shows Cumulative CW Jammer Post Code Mixing Attenuation Levels for PRN#1 accounting for the attenuation due to predetection integration in the GPS receiver. Note that GPS receivers using longer predetection integration times tend to attenuate line jammers more strongly on a statistical basis. This is because the narrower filter response presents a more difficult target. With a 20 msec PIT, strongest responses occur when the CW jammer gets translated via the C/A code mixing process to within ± 25Hz of the desire GPS signal's center frequency[17]. With a 2.5 msec PIT, the corresponding range is ± 200 Hz.

Table 3 shows attenuation values for confidence levels of 50% and 90%.

Table 3: CW Jammer Attenuations at 50% and 90% Confidence Points

Predetection Integration Time	90% Of Line Attenuations Down by More Than	50% Of Line Attenuations Down by More Than
20 msec	**44.7 dB**	**60.2 dB**
5 msec	**32.7 dB**	**47.6 dB**
2.5 msec	**30.0 dB**	**41.0 dB**

[17] Each GPS signal has a distinct center frequency within about ± 5kHz of 1575.42 MHz because of Doppler and receiver oscillator effects.

Figure 10: Sin(ω_eT/2)/ (ω_eT/2) Filter Response

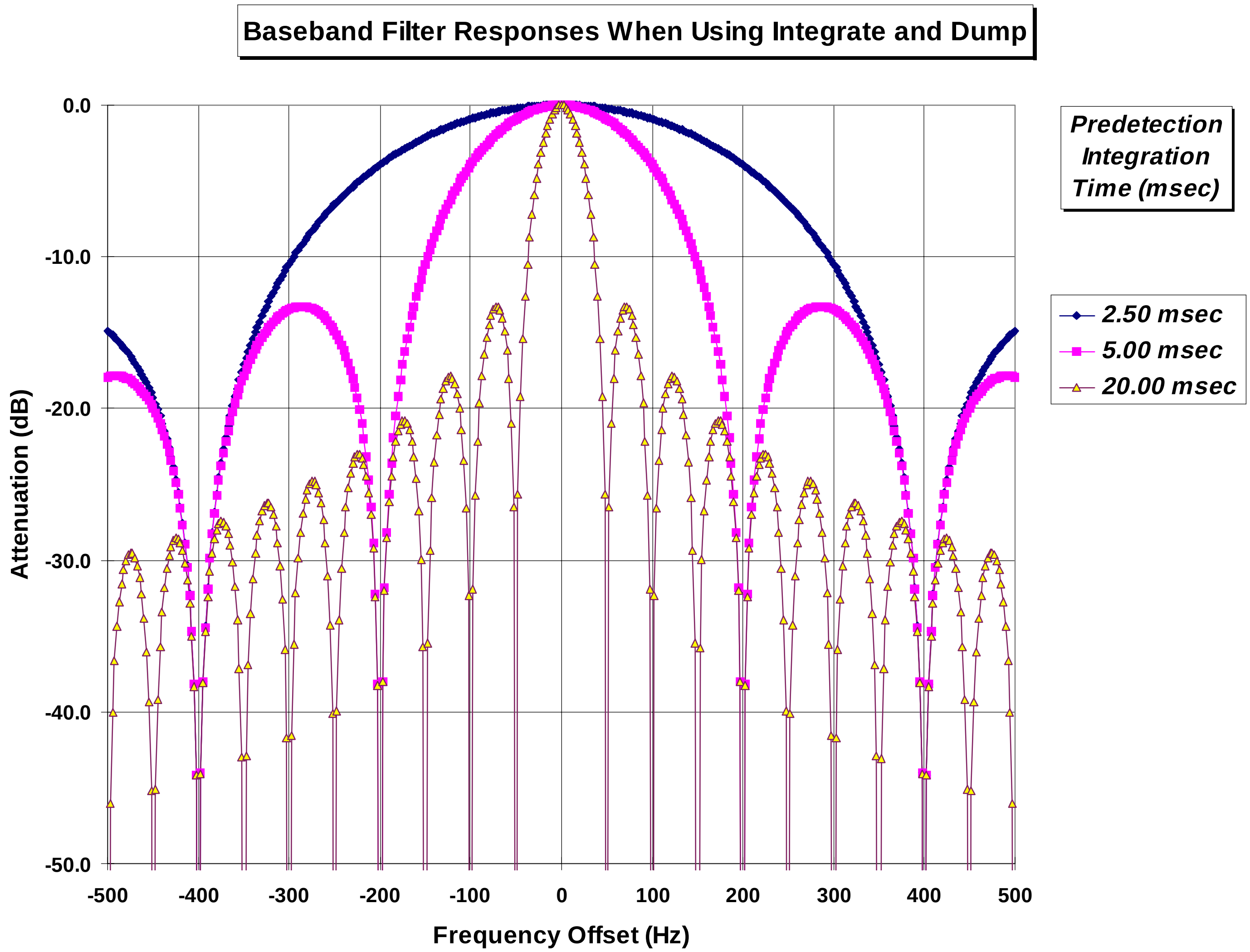
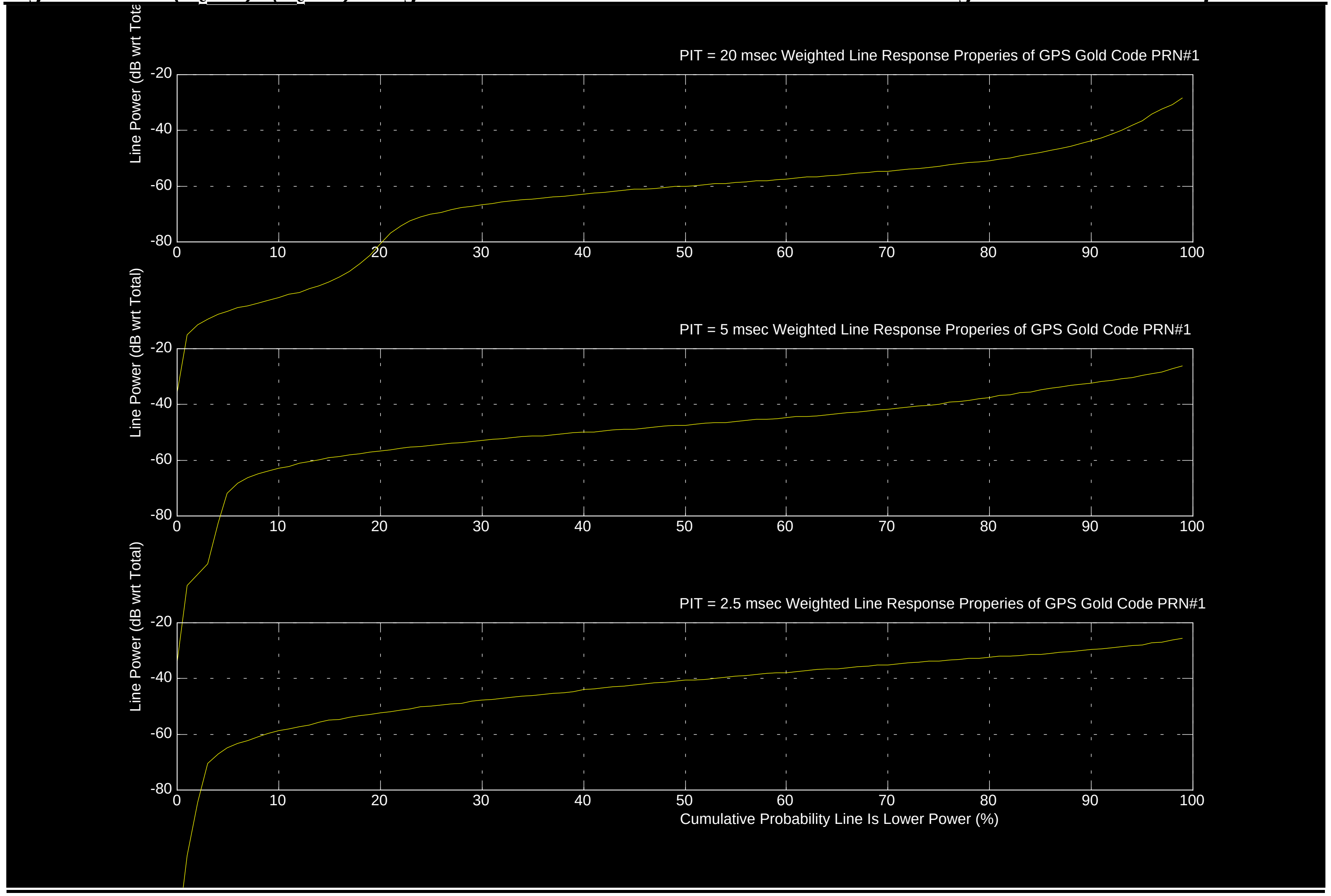


Figure 11: Sin(ω_eT/2)/ (ω_eT/2) Weighted Cumulative CW Jammer Post Code Mixing Attenuation Levels for PRN#1



We now come to the question of GPS receiver desensitization. Table 4 computes thermal noise out of the preamplifier referenced to the input for predetection integration times of 20, 5, & 2.5 msec and computes total noise in the associated baseband equivalent noise bandwidth via:

$$N(dBm) = N_0(dBm/Hz) - 10\log_{10}(PIT) \quad \textbf{\textit{(Equation 3)}}$$

where:

N is thermal noise power out of predetection integration (dBm)
N_0 is thermal noise power spectral density (dBm/Hz)
PIT is predetection integration time (seconds)

This is the amount of thermal noise seen at the input to the PLL discriminator.

Table 4: Computation of Thermal Noise in Predetection Bandwidth

Predetection Integration Time (msec):	**20.00**	**5.00**	**2.50**
Baseband Equivalent Noise Bandwidth(Hz):	**50.00**	**200.00**	**400.00**
Antenna Temperature (K):	**300.00**	**300.00**	**300.00**
GPS Receiver Noise Figure (dB @290K):	**1.50**	**1.50**	**1.50**
GPS Receiver Noise Temperature (K):	**119.64**	**119.64**	**119.64**
System Noise Temperature (K):	**419.64**	**419.64**	**419.64**
Total Thermal Noise Power (dBm/Hz):	**-172.37**	**-172.37**	**-172.37**
Thermal Noise Power In Reference Bandwidth (dBm):	**-155.38**	**-149.36**	**-146.35**

To compute jammer power out of the predetection integration process we use the equation:

$$I_{GMPCS}(dBm) = EIRP_{GMPCS}(dBm) + G_{GMPCS}(dBic) - PL(dB) - LR_{90}(dB) + 10\log_{10}(M) \quad \textbf{\textit{(Eqn. 4)}}$$

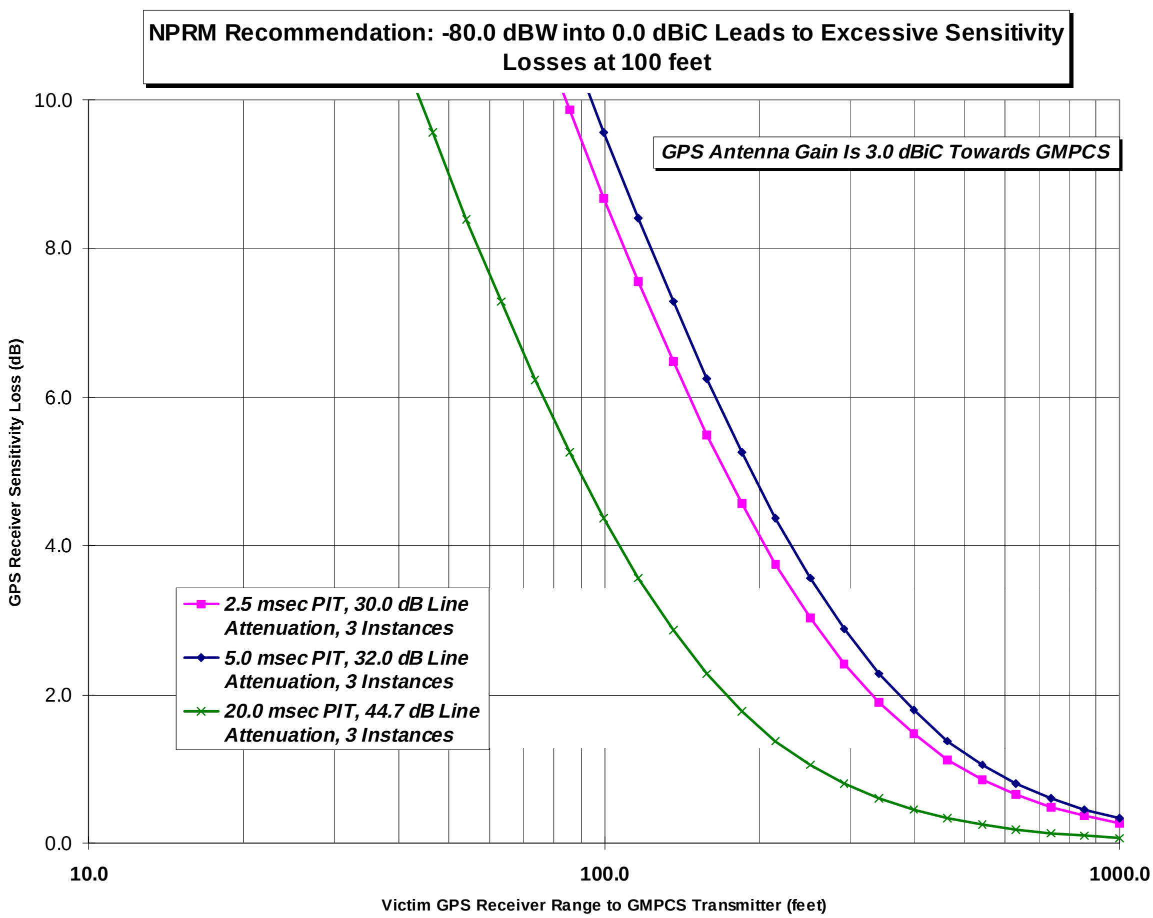
where:

$EIRP_{GMPCS}$ is GMPCS Effective Isotropic Radiated Power per Line Jammer (dBm)
G_{GMPCS} is GPS receiver gain towards GMPCS transmitter (dBic)
PL is free space path loss (dB)
LR_{90} is 90% confidence Line Attenuation from Table 3(dB)
M is the number of Line Jammers

Once again, this is the amount of GMPCS interference that is seen at the input to the PLL discriminator. Equations 3 & 4 can then be used to compute GPS receiver desensitization via equation 2. Justification for using only a 90% confidence level is that each C/A code has a different line structure and CW jamming that is problematic for one SV may have little effect on another. If one SV gets jammed out, there may be another that can be used with only a little degradation in Dilution Of Position (DOP).

Figure 12 shows GPS receiver desensitization as a function of range using the NPRM narrowband limits assuming that GMPCS interference is CW and that there are three equal power spurs[18] in the GPS frequency band. Again, the GPS receiver's antenna gain toward the GMPCS terminal is 3 dBi.

Figure 12: GPS Receiver Desensitization Using NPRM GMPCS Emission Limits



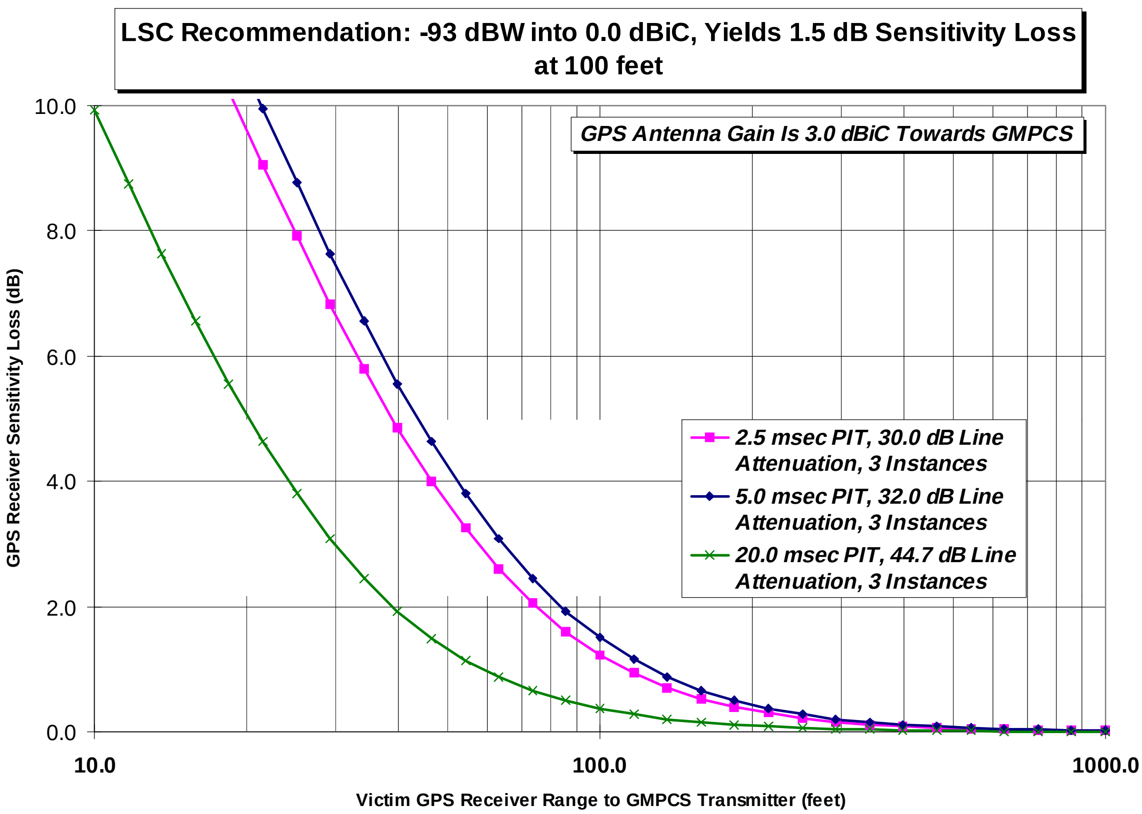
We see that the Multiplex receivers (5 and 2.5 msec PIT) are most sensitive to narrowband jamming but that all receiver types show significant desensitization at 100

[18] Rather than allow an unlimited number of spurs within the radionavigation band we suggest limiting he number and specifying it. Otherwise the emission limits per spur will need to be tightened

feet. Referring back to Table 1; the Multiplex receivers are also they type most vulnerable to desensitization.

Figure 12 shows results using the recommended level of -93 dBW/700 Hz EIRP. Now, desensitization is limited to 1.5 dB or less for all receiver types. This is a minimum protection assuming only one emitter. Again, the presence of multiple GMPCS emitters is potentially much more harmful because of power aggregation.

Figure 12: GPS Desensitization Using LSC Recommended GMPCS Emission Limits



Conclusions and Closing Remarks

The above analysis has shown NPRM protection levels for radionavigation systems to be wholly inadequate. No consideration has been given to the possibility of multiple handsets in deriving the FCC's proposed standard. The FCC has shifted direction from 98-68 and WRC-92 and now proposes to protect only a very limited subset of incumbent GPS/GLONASS users, namely airborne precision approach aviation users. This is in direct contradiction to the Vice President's stated policy with regards to GPS. No provisions or reasonable protection has been made for the majority of incumbent GPS/GLONASS users and as this comment has shown, FCC proposed GMPCS out of band emissions can and will adversely affect incumbent GPS users at ranges greater than 1000 feet. We would ask the FCC its rational for steering these proceedings away from a general protection of incumbent radionavigation users (as provided in WRC-92 discussions and 98-68) towards a very limited subset of aviation users.

NPRM proposed emission limits were derived for avionics applications assuming a -10 dBi GPS receiver antenna gain towards a single GMPCS terminal. This is a best case analysis not appropriate for deriving protective emission limits for the majority of incumbent GPS users. In other safety of life and radionavigation applications GPS antenna gains towards GMPCS can easily be 13 dB higher (+3dBi gain). As a consequence, GMPCS emission limits should be tightened an additional 13 dB to the LSC recommended values in order to provide protection against even a single GMPCS emitter. Failure to due so will be in direct contradiction to the Vice President's intent for GPS signal protection.

Finally, we would like to reemphasize that needed GMPCS emission limits can be relaxed considerably by requiring GMPCS to use Left Hand Circular Polarization. This would appear to benefit GMPCS independent of radionavigation questions because the wide range of GMPCS Satellite to Earth Terminal orientations favors the use of circular polarizations over linear polarizations.

Respectfully submitted,

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