Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of	)	
	)	
Spectrum Policy:	)	
	)	
Solicitation of Public Comment	)	ET Docket No. 02-135
by the Spectrum Policy Task Force	)	
	)	
	)	
To: The Commission		

COMMENTS OF

Statewide Wireless Network

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January 24, 2003

Contents

I. INTRODUCTION

1. These comments from the Statewide Wireless Network, under the New York State Office for Technology (NYS-OFT), present the recommendations and concerns of the State of New York with regards to the Spectrum Policy Task Force Report produced under FCC ET Docket No. 02-135. This Docket represents efforts by the Commission to address the need to improve and enhance its spectrum policies as we continue forward in to the 21st century. We applaud the Commission for creating a forum to address the changes necessary to such spectrum policies. We also sincerely thank those who's hard work and efforts were responsible for the creation of the Report to which we provide comment herein.

2. The New York State Office for Technology, on behalf of the State of New York, is in the process of procuring a new Statewide Wireless Network (SWN) for State, Federal and Local Governmental entities that operate within New York State's geographic borders. SWN will provide an integrated mobile radio communications network that will be utilized by both Public Safety and Public Service agencies in New York State. It will provide a digital, trunked architecture that will offer both voice and data capabilities. It will be used in day-to-day operations, as well as for disaster and emergency situations, to more effectively and efficiently coordinate the deployment of all levels of government resources to such incidents. It will also enhance international coordination along the US/Canadian border, and will play a critical role in supporting the homeland defense efforts within the State of New York.

3. The State of New York has a large stake in the outcome of any current or future spectrum policy decisions, especially where these affect the performance, capability, capacity, cost, or construction timeline of the SWN system. The Spectrum Policy Task Force has provided many excellent recommendations within their Report, but they need to be balanced by the needs of Public Safety, who have very unique requirements and extremely limited resources available.

II. KEY ELEMENTS OF SPECTRUM POLICY RECOMMENDATIONS

4. The Task Force is right to recommend[1] policies that "permit broad, highly flexible use within technical parameters of the allocation"[2]. Such policies would allow for efficient use of the spectrum, without introducing additional interference to incumbent and authorized users. However, the Task Force also recommends that polices that "permit traditionally narrow services to lease excess capacity to other services[3]" also be considered. The Commission should approach such policy decisions with great caution, especially with regard to Public Safety Spectrum allocations. If the technology to support instantaneous return of spectrum to Public Safety is not completely capable of doing so, the reliability and integrity of Public Safety communications could be breached.

5. The task force has also called for an investigation into rule changes that would enable the lowering of permitted power in urban areas, and the increasing of permitted power in rural

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[1] SPECTRUM POLICY TASK FORCE REPORT, Federal Communications Commission ET Docket No. 02- 135, November 2002

[2] *Id.* § IX-A-1 (p.64), as well as § V

areas[4]. This recommendation appears to be a dual-edged sword. If the intent is to permit high-power broadcast operations to convert to low power distributed transmission system operation within their present service area, then this will reduce the interference range of current high power operations and promote greater overall spectrum efficiency. However, non-broadcast operations, specifically Public Safety operations may require higher signal levels in urban areas where portable in-building operations are required and building construction results in higher signal attenuation. Furthermore, in many rural areas (e.g. in the Northeast U.S.) higher frequency Public Safety operations are often terrain-limited, which implies that increased radiated power will do little to increase either the reliability or range of communications. These increases will, however, almost certainly increase the interference range from the transmitter.

6. An often-overlooked solution to the near far problem (see Appendix I - (a) for an overview of this problem, as well as Section IV) is the shaping of antenna patterns to provide uniform flux density over the service area. The Task Force's recommendations regarding this[5] should be given serious consideration. For designs where data rate requirements are uniform throughout the service area, this would represent a more responsible use of the spectrum, and would eliminate much of the interference that is currently being studied in the Commission's Proceeding on 800 MHz Interference[6]. Given this, the Commission should consider

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[3] *Id.*

[4] *Id.* § IX-A-2 (p. 64), as well as § V

[5] *Id.* § IX-A-3 (p. 64), as well as § V

[6] WT Docket No. 02-55, " In the Matter of Improving Public Safety Communications in the 800 MHz Band and Consolidating the 900 MHz Industrial/Land Transportation and Business Pool Channels"

incentives that facilitate the migration of Land Mobile, Cellular, and Broadcast services to more uniform flux density operations.

7. The Task Force also notes that the Commission should consider grouping future allocations based on mutually-compatible technical characteristics, and require improvements in the out-of-band interference performance of transmitters and receivers so as to possibly reduce the need for such grouping[7]. The State feels that, at a minimum, the FCC should consider grouping allocations for similar designs together (i.e. segregating noise-limited and interference-limited designs). This will reduce interference to noise limited services, and would allow sharper transmitter filters and lower out of band emissions (OOBE) for all services. This type of policy decision is right now being examined as the main solution to mitigating inter-service interference at 800 MHz (see 6). The State further feels that the reduction of OOBE is a critical need in order to ensure the survival of noise-limited systems, an issue that will be examined further within this response (Section IV and Appendix A).

8. Recommendations to "conduct periodic evaluations of allocation parameters with respect to evolving technology and uses", "time-limit spectrum rights and subject them to periodic review", and periodically " review spectrum rights and obligations, interference criteria, and definitions, and modify if appropriate"[8] are all critical in order for the Commission to avoid the types of design and technology conflicts that had led to the interference within the 800 MHz band. However, as noted[9] by the Task Force, spectrum users should be entitled to rely on rules remaining constant between the periodic reviews. This is especially important for

[7] see 2 § IX-A-6 (p. 64), as well as § V

[8] *Id.* § IX-A-7, 8 (p. 64), as well as § V

large systems such as SWN, in order to ensure that changes to spectrum policy will not affect system design while construction is either ongoing or in-progress.

III. Spectrum Usage Model Recommendations

9. According to the Task Force, the Commission should expand the use of both the exclusive rights and commons models, and move away from command-and-control models (with limited exceptions)[10]. Furthermore, it is stated that there should be a rules transition from legacy command-and-control bands to more flexible rules (to the maximum extent possible), with only limited exceptions. The State understands that these models might serve to allow more innovation and spectrum availability, but notes that the "limited exceptions" should specifically encompass all Public Safety Operations. This is touched upon when the Task Force recommends that (the FCC) "continue to dedicate some spectrum on a command-and-control basis for Public Safety use"[11], but the State firmly believes that the command and control model should be applied consistently across all Public Safety spectrum allocations.

10. An interesting concept brought forward by the Task Force is that the Commission could address additional Public Safety needs through alternative "safety valve" mechanisms in order to increase the capacity of Public Safety systems during emergency situations[12]. Even if this were to be realized, it should not replace the need for Public Safety to maintain

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[9] *Id.*

[10] *Id.* § IX-D-23,24 (p. 65), as well as § VII

[11] *Id.* § IX-D-26 (p. 65), also § VII

[12] *Id.* § IX-D-27 (p. 66), also § VII

capacity reserves for emergency situations. There is no guarantee that the technologies[13] that would enable enhanced spectrum easement rights based upon Public Safety priority can effectively shift such spectrum quickly or effectively enough so as not to limit Public Safety's response or communications capabilities during the incident. For the same reason, we are wary of any possible policy that allows Public Safety to lease spectrum to commercial services during low capacity requirement periods[14]. This could set a precedent such that Public Safety could in fact be Regulated under an Exclusive Use model, which might ultimately lead to a situation where Public Safety's capabilities could be reduced due to technology limitations in the spectrum easement control mechanisms.

IV. INTERFERENCE AVOIDANCE RECOMMENDATIONS

11. Some of the most far-reaching recommendations that are put forth by the Task Force deal with interference avoidance and mitigation. While there are many recommendations that would improve the use of the radiocommunications spectrum, there are many whose consistent theme signifies a trend toward some disturbing policy shifts.

12. The recommendations that the State supports are those that enable both users and regulators to better understand the spectrum environment, and its noise and interference levels. These include :

- Obtaining better characterization of the noise floor, and adopting a standard method for measuring this noise floor[15],

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[13] Also see the Cognitive Radio discussion in Section V of this Response

[14] see 11, also at § IX-D-28 (p. 66)

[15] see 1 § IX-B-10 (p. 64) and § VI

- Creating a public/private partnership for a long term noise monitoring network, and archiving the resulting data for use by both the FCC and the public[16],

- Issuing a Notice of Inquiry to characterize current and future receiver environments as well as explore issues such as, performance parameters, and protection for legacy receivers[17],

- Awarding a contractual study to evaluate receiver performance in the current environment[18],

- Promoting voluntary receiver performance requirements through industry groups[19],

- Considering incentives for use of advanced receivers[20],

- Promoting transmitter enhancements for interference control, such as[21]

  - Fostering technologies that enhance uniform signal levels throughout a service area;

  - Promoting greater use of automated transmitter control systems; and

  - Considering tightening out-of-band emission limits over time.

- Improving communications on interference issues with the public, such as[22]:

  - Harmonizing interference language in FCC rules as well as applicable international rules,

  - Ensuring consistent and appropriate use of this interference terminology,

  - Developing technical bulletins that explain interference rules for all radio services,

  - Developing a "best practices" handbook,

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[16] *Id.*, § IX-B-11 (p. 64)

[17] *Id.*, § IX-B-14 (p. 65)

[18] *Id.*, § IX-B-15 (p. 65)

[19] *Id.*, § IX-B-16 (p. 65)

[20] *Id.*, § IX-B-17 (p. 65)

[21] *Id.*, § IX-B-18 (p. 65)

13. It is clear that these steps will enable the FCC and the general public to better understand both the noise and *pollution* levels that exist in the radio spectrum, as functions of time, space and frequency. It is hoped that this will not only assist system designers, regulators and technologists, but also clearly illustrate the need to reduce or eliminate out of band interference and spurious emissions that pollute much of the Public Safety spectrum landscape. The need to clean up this environment is critical in order to sustain and allow large-scale Public Safety systems to be developed at fiscally achievable costs.

14. As previously noted, the State also ***disagrees*** with many of the Task Force recommendations regarding interference issues and policy changes. These represent a disturbing trend toward moving Public Safety communications systems to interference-limited designs, a trend that has serious ramifications.

15. The Task Force has introduced a new concept, the so called "interference temperature"[23] to quantify acceptable levels of interference as a long-term objective. The State feels that this concept, while interesting, does not translate well into Public Safety operations because:

    (1) It could allow for unlicensed devices to operate co-channel with Public safety (albeit below the "temperature" floor), and more importantly

    (2) It is based upon the fact that the environment is interference limited, with interference pockets distributed in the previously-mentioned three primary dimensions (i.e. time, space, and frequency).

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[22] *Id.*, § IX-B-19 (p. 65)

[23] see 1 § IX-B-9 (p. 64) and § VI

16. The Task force further recommends that the Commission include receiver tolerances in regulation.[24] These would be used until it (the Commission) can migrate to an "interference temperature"-based regulatory scheme, and will serve in the long term where the use of an interference temperature would be not be applicable. The State feels allowing the Commission to establish rules or performance requirements for receivers would be a prudent recommendation, but to do so solely as an interim step to migrating to interference-temperature-based regulations is unacceptable.

17. The Task Force also recommends (in no uncertain terms) that the Commission migrate to interference-limited policies[25], where the "interference temperature" concept should form the basis for better defining interference rights[26]. There are many reasons that this trend towards interference-limited policies cannot continue to procreate, specifically with regards to Public Safety allocations:

- These interference-limited designs require higher signal levels in order to provide reliable communications
- These high signal requirements directly reduce the reception range from the transmitter for reliable communications
- This range reduction directly increases the siting requirements (and costs) of Public Safety systems.
- This siting increase indirectly limits the available capacity for Public Safety systems

[24] see 1 § IX-B-12 (p. 65) and § VI

[25] *Id.* § IX-B-13 (p. 65) and § VI

[26] *Id.* § IX-B-21 (p. 65) and § VI

18. The State has provided some examples and clarification of these concepts within Appendix A of this response. This Appendix is organized as follows: (b) illustrates the necessary increase in signal levels required to mitigate typical interference scenarios within a noise-limited Public Safety system, (c) takes these increased signal requirements and translates them into coverage range and coverage area reductions, (d) shows the effects that these coverage reductions have upon system siting, and (e) describes how this reduced coverage actually reduces the capacity that is available to Public Safety.

19. Based upon the concepts presented here, the forced migration of Public Safety into interference-limited designs would be both fiscally irresponsible and spectrally wasteful. Public Safety cannot shoulder the burden of costly policy shifts in a time where it is called upon to do more with less. Furthermore, pushing Public Safety into these types of designs would work against the intent of the policy itself; in other words spectrum efficiency would be <u>reduced</u>, not enhanced.

20. Raising the allowable noise environment, as occurs with interference limited designs, directly increases pollution in the electromagnetic spectrum, and creates a significantly increased burden for tower site environmental issues -- a direction opposite to the goals of the National Environmental Protection Act.

V. PROMOTING ACCESS TO SPECTRUM RECOMMENDATIONS

21. In considering methods to promote access to spectrum, the Task Force considered methods for enabling additional spectrum access for unlicensed devices. These methods included newer coordination techniques such as the use of band mangers, and opportunistic/dynamic

use of existing bands through the use of technologies such as cognitive radios to find "white space" in existing bands. The State feels that while the band managers concept may be a very effective way to manage commercial or commercially-used spectrum, it is too poorly defined and regulated for use within Public Safety allocations. As far as cognitive radios and related technologies are concerned, the State closely follows the activities of both the Software Defined Radio Forum and the Department of Defense with regard to these technologies. Although they hold great promise, these technologies are not currently able to provide reliable interference-free operations or opportunities for the sharing of dedicated Public Safety bands. Furthermore, it appears that unless omnipresent and interconnected real-time sensor networks are in place over an entire service area, these may never be able to provide interference free operations.[27]

VI. CONCLUSION

22. We again applaud the Commission for creating a forum to address the changes necessary to review such spectrum policies, and sincerely thank those whose hard work and efforts were responsible for the creation of the Report to which we have provide comment herein.

23. The State of New York has a large stake in the outcome of any current or future spectrum policy decisions, especially where these affect the performance, capability, capacity, cost, or construction timeline of the SWN system. The Spectrum Policy Task Force has provided many excellent recommendations within their Report, but many more need to be balanced by

[27] also see *A White Paper on The Exploitation of "Spectrum Holes",* Motorola, October 28, 2002

the needs of Public Safety, who have very unique requirements and extremely limited resources available.

24. In summary, New York State is concerned that policy changes may be developed that allow for sharing of Public Safety spectrum where this might further lead to interference and resource contention in the event of a crisis. The State must strongly emphasize that the forced migration of Public Safety into interference-limited designs would be both fiscally irresponsible and spectrally wasteful, and that Public Safety (and Local, State and Federal Government) cannot shoulder the additional financial burden that would results from such an ineffectual and ill-conceived policy.

Respectfully Submitted,

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APPENDIX A, INTERFERENCE EFFECTS ON PUBLIC SAFETY SYSTEMS

(a) The Near/Far Problem

The infamous near/far problem occurs when users are relatively far from their base transmitters, and relatively close to an interference source. This interfering source radiates power that is being coupled into the intermediate frequency (IF) or baseband filter of the victim receiver. This interfering power may be due to near or far adjacent channel interference, strong out-of-band-emission (OOBE) levels, transmitter-generated intermodulation products, and even high level far out-of-band signals generating intermodulation products within the victim receiver. The interfering source can emanate from either a base station transmitter or a portable device

Figure 1 and Figure 2 illustrate a typical near/far scenario that results in interference to subscriber receivers. In these figures notice that there are two types of locations where interference becomes much more likely. The most common is when a subscriber unit is far from its associated base station, and close to an interfering source. In this case, the loss experienced by the desired signal at the subscriber unit is greater than the loss of the undesired signal. Therefore, even though the undesired signal is not co-channel with the desired signal, interference may still result. The other case seen here is when cellular subscribers are operating on the edge of their service area, where their automatically controlled power output is at its highest. If this occurs in tandem with a low-level desired signal (i.e. the victim being relatively far from its base transmitter), then again, interference will result.

Not shown, but also a frequent cause of interference is when the undesired signal is being used by an interfering subscriber near the desired base receiver, at the same time that the victim receiver is trying to communication on it's reverse link. This situation results in interference at the base receiver, where the undesired signal degrades the reception of the desired signal.

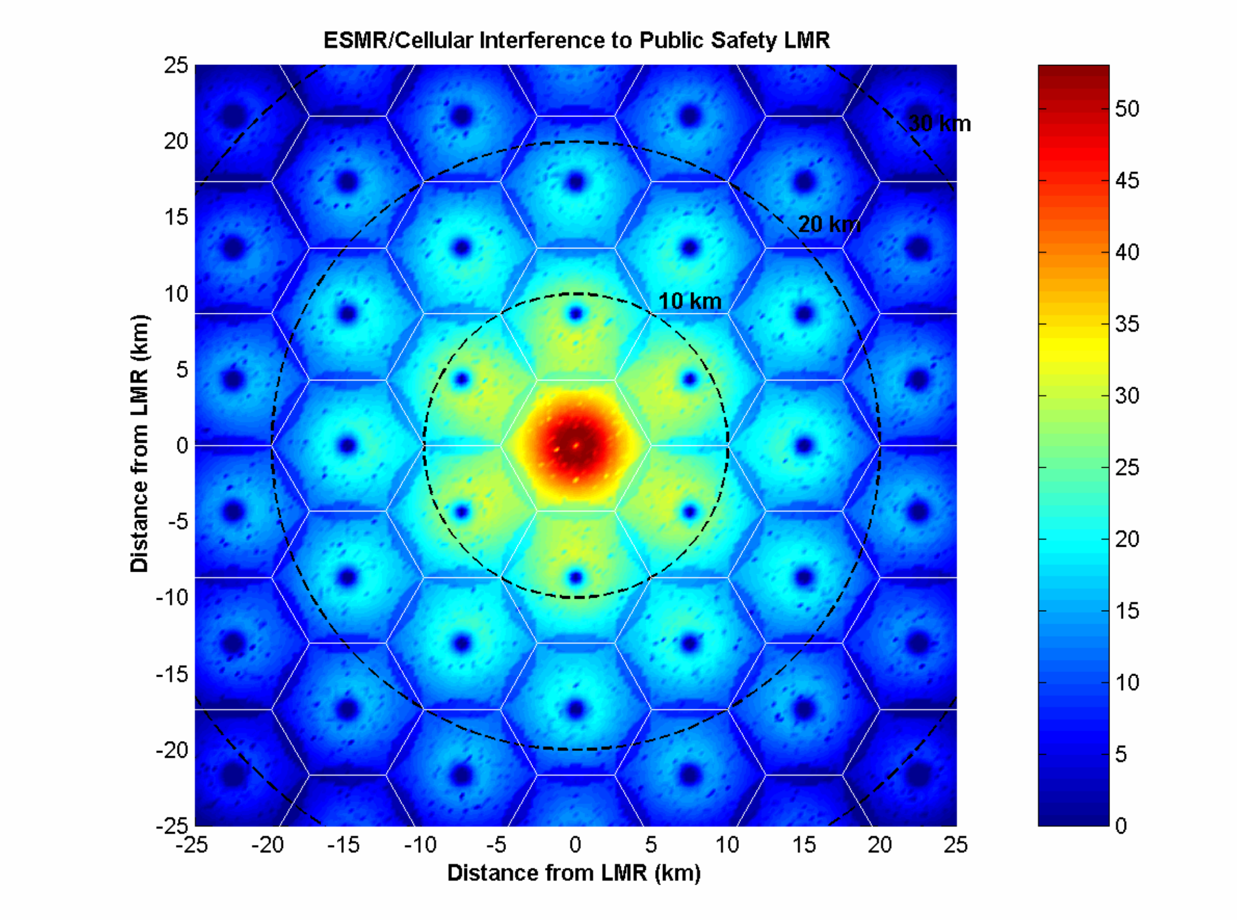

Figure 1: S/(ΣI+N) Distribution in Near/Far Problem

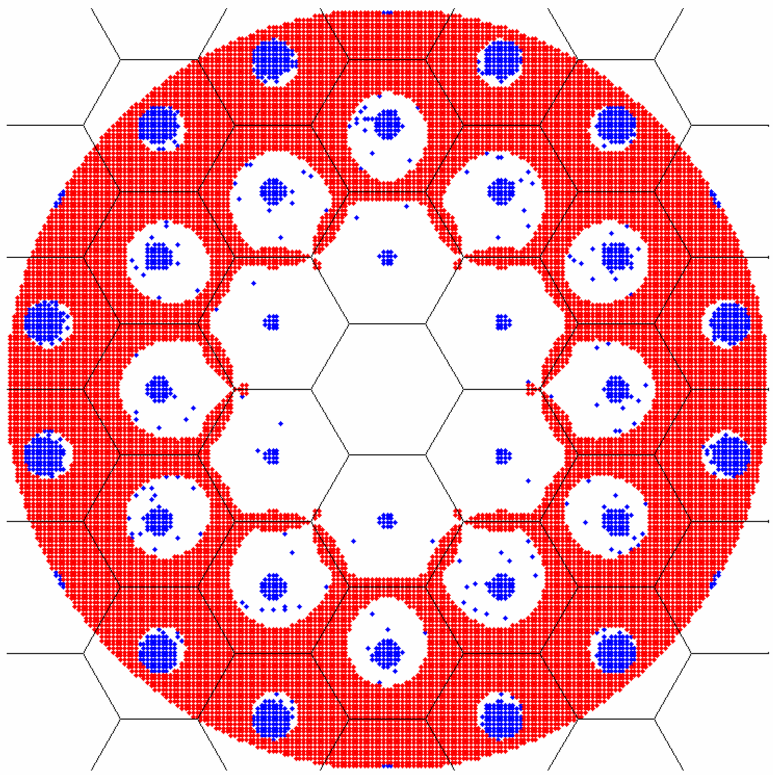

Figure 2: Locations of Interference Due to the Near/Far Problem

(b) Necessary Increase in Signal Required for Interference Mitigation

In this section, Table 1 illustrates the effect that both interference levels, and noise floor degradation have upon the necessary desired signal level, in order to ensure that a system design can maintain a fixed communications reliability. These tables use the following parameters:

- *Receiver Noise Floor:* *-126.32 dBm (ENBW = 6 kHz, NF = 10 dB)*
- *Mean Interferer Level:* *-128.0 dBm in Desired IF of Victim Receiver*
  (this interferer will experience antenna loss/gain)
- *Lognormal Variance:* *5.8-dB and 8-dB*
- *Faded S/(I+N) Requirement:* *17-dB (Delivered Audio Quality of 3.0 for C4FM)*
- *Uncorrelated Signal and Interference Level(s)*
- *Where Applicable, Portable Antenna Losses of 10-dB (relative to 1/2 wave dipole)*

And correspond to the following cases:

- *N:* *Noise Only*
- *N+I:* *Noise and a Single Interferer*
- *N+2I:* *Noise and Two Equal Interferers*
- *N+OOBE3:* *A 3-dB Degradation of Noise Floor due to OOBE, etc*
  (this degradation is independent of antenna loss/gain)
- *N+I+OOBE3:* *A Single Interferer, along with a 3-dB Noise Floor Degradation*
- N+I OOBE5: A 5-dB Degradation of Noise Floor due to OOBE, etc

Table 1: Necessary Power Increase due to Interference Effects

Noise Floor -126.22 dBm
Sigma 5.8 dB

	Case	Signal (dBm) For Reliability Target 90%	95%	97%	Increase (dB) From Noise Limited Case 90%	95%	97%
Mobile	N	-101.8	-99.7	-98.4	N/A	N/A	N/A
	N+I	-96.5	-93.6	-91.6	5.3	6.2	6.8
	N+2I	-94.3	-91.4	-89.5	7.5	8.4	9.0
	N+OOBE3	-98.8	-96.7	-95.4	3.0	3.0	3.0
	N+I+OOBE3	-94.5	-91.5	-89.6	7.3	8.2	8.8
	N+I+OOBE5	-92.9	-89.9	-88.0	8.9	9.8	10.4
Portable	N	-91.8	-89.7	-88.3	N/A	N/A	N/A
	N+I	-91.5	-89.4	-88.0	0.3	0.3	0.3
	N+2I	-87.8	-84.9	-82.9	4.0	4.9	5.4
	N+OOBE3	-88.8	-86.7	-85.3	3.0	3.0	3.0
	N+I+OOBE3	-88.7	-86.6	-85.2	3.1	3.1	3.1
	N+I+OOBE5	-86.7	-84.6	-83.2	5.1	5.1	5.1

Noise Floor -126.22 dBm
Sigma 8.0 dB

	Case	Signal (dBm) For Reliability Target 90%	95%	97%	Increase (dB) From Noise Limited Case 90%	95%	97%
Mobile	N	-99.0	-96.1	-94.2	N/A	N/A	N/A
	N+I	-92.6	-88.4	-85.8	6.4	7.7	8.4
	N+2I	-90.4	-86.3	-83.7	8.6	9.8	10.5
	N+OOBE3	-96.0	-93.1	-91.2	3.0	3.0	3.0
	N+I+OOBE3	-90.5	-86.4	-83.7	8.5	9.8	10.5
	N+I+OOBE5	-88.8	-84.8	-82.2	10.1	11.3	12.0
Portable	N	-89.0	-86.1	-84.2	N/A	N/A	N/A
	N+I	-88.7	-85.8	-83.9	0.3	0.3	0.3
	N+2I	-83.8	-79.7	-77.1	5.2	6.4	7.1
	N+OOBE3	-86.0	-83.1	-81.2	3.0	3.0	3.0
	N+I+OOBE3	-85.8	-82.9	-81.1	3.1	3.1	3.1
	N+I+OOBE5	-83.9	-81.0	-79.1	5.1	5.1	5.1

> 40 dBu (yellow)
> 50 dBu (red)
> 3 dB (blue)

Note that the current 40-dBu typical[28] limit of field strength at the edge of a service area is insufficient to mitigate *most* cases of noise floor degradation and interference that involve mobile operations, and *all* cases involving portable operations. Further note that in many cases the 50-dBu contour levels that have been discussed[29] by the Commission are also insufficient.

[28] The level upon which 800 MHz Public Safely service area protection is based

[29] see for example PETITION FOR RECONSIDERATION OF THE SECOND MEMORANDUM OPINION AND ORDER, SERVICE RULES FOR THE 746-764 AND 776-794 MHZ BANDS AND REVISIONS TO PART 27 OF THE COMMISSIONS RULES, 17 FCC Rcd 13985, July 12, 2002

(c) Coverage Range Degradation due to Interference

Table 2, below, illustrates the effect that increased signal levels have upon the range and coverage area of Public Safety systems. The increased power levels are due to interference and/or noise floor degradation, and are necessary to ensure that a system design can maintain reliable communications.

Table 2: Typical Range and Coverage Losses due to Necessary Power Increases

Edge of Contour (EOC) Level	EOC Level Increase	(Final Range)/(Original Range)			(Final Area)/(Original Area)		
(dBm)	(dB)	Open	Suburban	Urban	Open	Suburban	Urban
-102	**0**	100%	100%	100%	100%	100%	100%
-101	**1**	96%	95%	93%	93%	90%	87%
-100	**2**	93%	90%	87%	86%	82%	76%
-99	**3**	89%	85%	81%	79%	71%	66%
-98	**4**	86%	79%	76%	73%	63%	58%
-97	**5**	82%	74%	71%	67%	54%	50%
-96	**6**	79%	69%	67%	62%	48%	44%
-95	**7**	76%	65%	62%	58%	42%	38%
-94	**8**	73%	60%	58%	53%	36%	34%
-93	**9**	70%	56%	54%	49%	32%	29%
-92	**10**	67%	52%	50%	45%	27%	25%
-91	**11**	64%	49%	47%	41%	24%	22%
-90	**12**	61%	46%	44%	38%	21%	19%
-89	**13**	59%	43%	41%	35%	18%	17%
-88	**14**	56%	40%	38%	32%	16%	15%
-87	**15**	54%	37%	36%	29%	14%	13%
-86	**16**	51%	35%	33%	26%	12%	11%
-85	**17**	49%	32%	31%	24%	10%	9%
-84	**18**	47%	30%	29%	22%	9%	8%
-83	**19**	44%	28%	27%	20%	8%	7%
-82	**20**	42%	26%	26%	18%	7%	7%
-81	**21**	40%	25%	24%	16%	6%	6%
-80	**22**	37%	23%	22%	14%	5%	5%
-79	**23**	35%	21%	21%	12%	5%	4%
-78	**24**	32%	20%	19%	10%	4%	4%
-77	**25**	30%	19%	18%	9%	3%	3%

(d) System Siting Effects due to Interference

This section illustrates the effect that the parameters presented in Sections (b) and (c) of this Appendix have upon large system designs. Figure 3 shows an example of the number of hexagonal cells[30] required to provide coverage for New York State[31], assuming that there is no terrain blockage or diffractive effects. In this figure, it is seen that for a noise-limited design the state could be covered with 364 cells. However, when the noise floor and interference degradation rises, so does the number of sites required to maintain reliable communications. A 3-dB increase in required signal levels almost doubles the number of transmitter locations (a ratio of 1.51), and a 10-dB increase multiplies the number of required sites by a factor of almost four (a ratio of 3.89). The number of sites is proportional to the cost of a Public Safety (or any) system, and Public Safety does <u>not</u> have a market case for increasing both siting and system costs. Thus, it is clear why large Public Safety systems require that noise and interference levels are as low as possible.

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[30] This accounts for the cell overlap that is present for circular coverage cells.

[31] Since there is a New York Statewide system currently under procurement, it must be noted that this is an illustrative example only. This does not imply that the number of sites presented here is representative of the final system design.

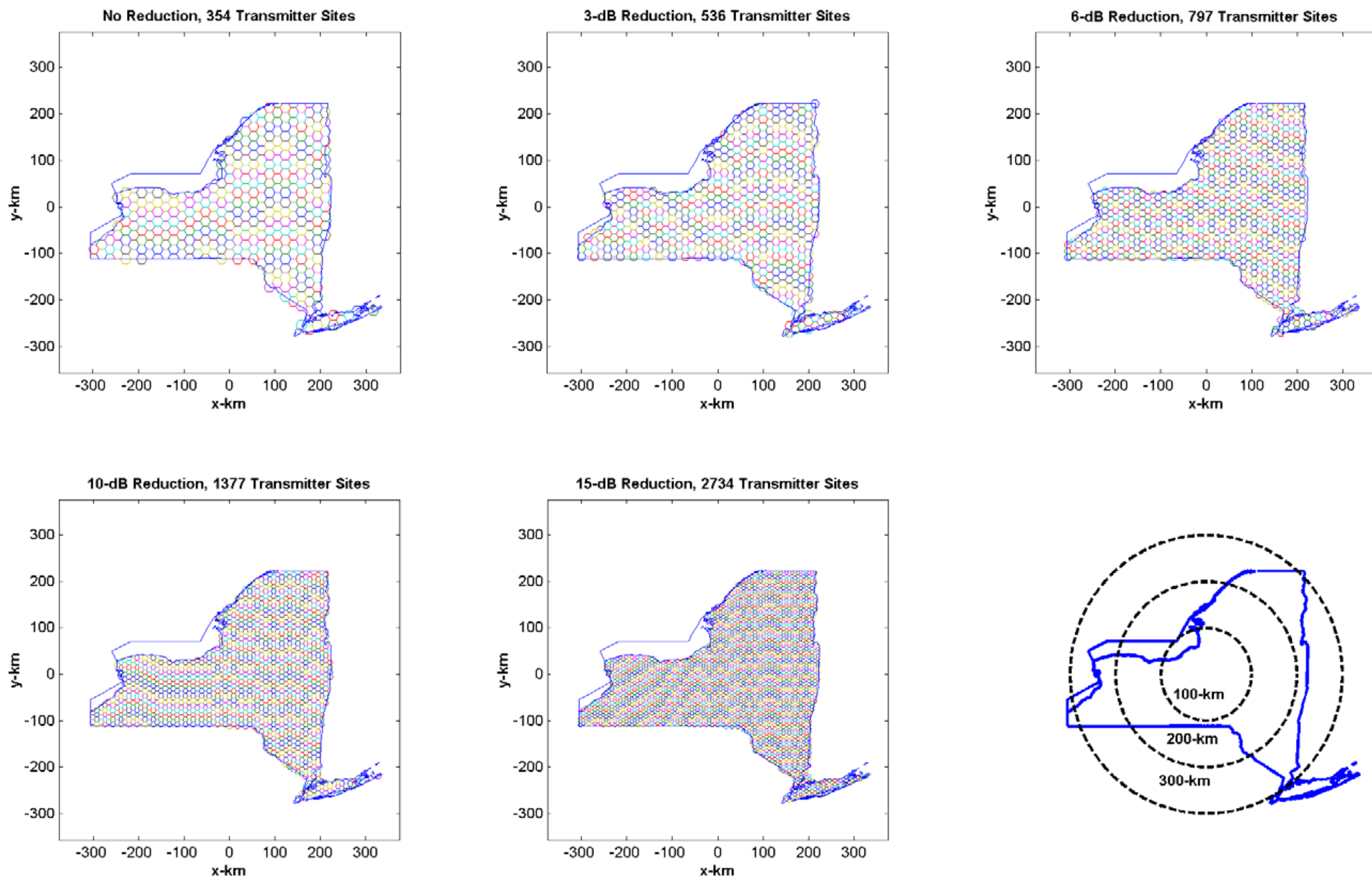

Figure 3: Increased Statewide Siting Requirements due to Interference Degradation

(e) System Capacity Effects due to Interference-Limited Designs

The explosive growth of the wireless communications industry in the 1980's was a direct result of the concept of "cellular design". It was seen that if transmitter locations were located on a cellular (or other tessellated type) grid and co-channel frequencies were assigned in specific repeating patterns, then geographic capacity could be enhanced by reducing the size of the representative cells. Furthermore, this increased capacity could occur while maintaining consistent and adequate signal to interference (S/I) levels, always meeting a minimum Quality of Service level. These came to be called "interference-limited" systems, since the limiting factor for communications reliability was only the interference level, which was much higher than the thermal noise level of the system receivers. These days, nearly all cellular and PCS systems exploit the concept of interference-limited system designs in order to enjoy maximum capacity from a fixed set of channels (their frequency block). However, this expansion in capacity does not hold for Public Safety systems.

The cellular interference-limited design exploits the fact that as more spectrum is reused, more capacity is made available. This however, is based upon the notion that all communications are point-to-point within the system, and that each call can load at most two transmitter cells. Public Safety voice communications do not meet this criterion. A very high percentage of Public Safety communications are point-to-multipoint within a talkgroup structure. Because of this, every cell not only experiences all the traffic of a particular *user* registered within the cell, but also *all* of the traffic from the associated members of the talk group (or talkgroups) corresponding to the user located within the cell. While this at first glance seems wasteful, it clearly corresponds with the notion of providing Public Safety services. In other words, in order to protect and serve the public over a given area, it is necessary to coordinate Public Safety personal *simultaneously over the entire area*.

For purposes of discussion let's assume that we have a countywide Public Safety communications system. Because each site within the system will experience nearly identical traffic loading[32], each site must have enough channel resources to essentially handle all the users within the county. Lets set a fixed channel requirement of *N*-Channels in order to provide a sufficiently low blocking probability for accessing the system. If the system has *M* transmitter sites, then the total number of channels required by the county is *MN*. It is clear that the channel requirements increase linearly with the number of transmitter sites. Furthermore, most counties are not large enough to allow co-channel reuse within their border; therefore *MN* distinct channels are required. This is the reason that simulcast systems have been popular; they return the channel requirement back to *M* channels, a number that is attainable in most localities[33].

The moral of the story is that, for Public Safety operations, unless simulcast is employed, increasing the number of sites actually increases the amount of channels required, which is equivalent to reducing the geographic spectral efficiency of the system. Although simulcast designs can help to mitigate this, simulcast is extremely difficult to implement for a large number of transmitter sites and is not expected to be available with TDMA and other spectrally efficient[34] technologies that use complex modulation with high bit rates.

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32 This assumes that at least one member of each talk group can be found within each site footprint or coverage area.

33 In most populated areas there is only a very limited amount of spectrum that can be made available.

34 Measured in terms of voice-paths/Hz. Note that what is really important is voice-paths/Hz/km^2

In terms of the parameters and examples illustrated in (b) through (d), lets look at the overall spectrum efficiency reduction that results from moving toward interference-limited designs. Figure 4 portrays two simple cases; both corresponding to a system that requires 10, 25-kHz channels in order to adequately support its operations. In the case on the left, we see what happens to the system when an increase of 6-dB is required to mitigate elevated noise and/or interference levels within a noise-limited system. The dotted black line shows the original coverage, with the red solid hexagons showing the increased siting necessary to support the increase in signal levels. Assuming that simulcasting is not an option, this case illustrates where a system that originally required only 250 kHz of total spectrum would now require 1 MHz of spectrum to support the same operations. In the case on the right, the degradation is now 10 dB, and the result is a seven-fold increase in spectrum (1.75 MHz) required to support the same operations. It is clear that when point-to-multipoint communications are required and simulcast operation is not practical, interference-limited designs will actually decrease the spectrum efficiency.

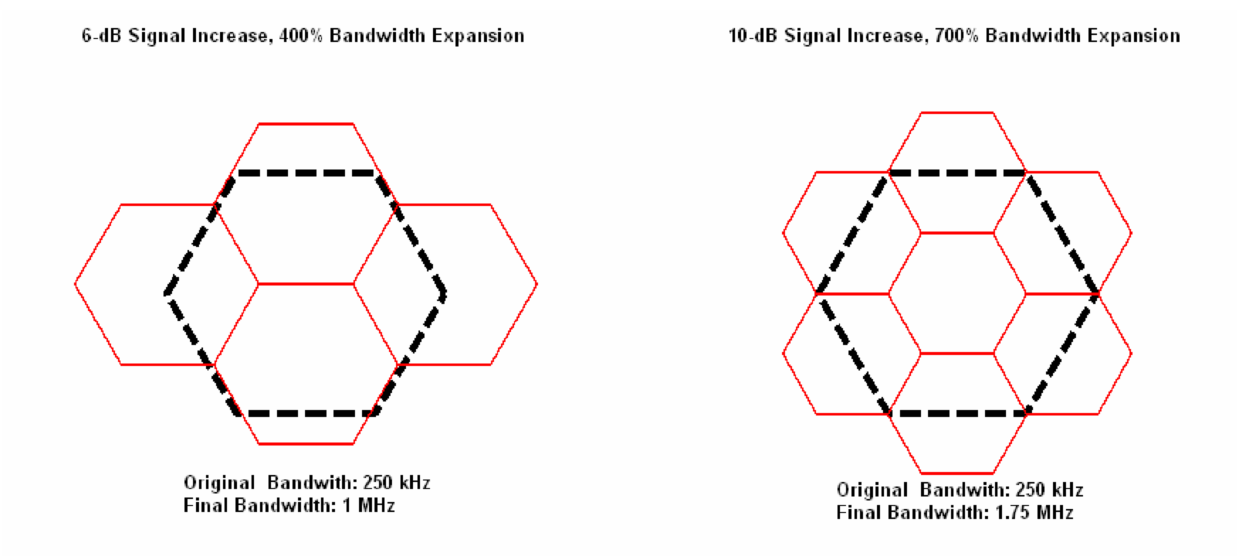

Figure 4: Bandwidth Expansion due to Interference Degradation