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January 18, 1999

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

BY HAND

Magalie Roman Salas, Secretary
Federal Communications Commission
445 Twelfth Street, S.W. - Suite TW-A325
Washington, D.C. 20554

Re: WT Docket No. 99-168
Service Rules for the 746-764 and 776-794 MHz Bands,
And Revisions to Part 27 of the Commission's Rules

Dear Ms. Salas:

Enclosed for filing in the above-referenced proceeding are an original and nine copies of the Comments of FreeSpace Communications in response to the Public Notice issued in this proceeding on January 7, 2000 (DA 00-31).

Please date stamp the additional copy provided herewith for that purpose and return the same to the bearer. Thank you for your assistance.

Sincerely,

Charles W. Logan

cc:
Chairman Kennard
Commissioner Furchtgott-Roth
Commissioner Ness
Commissioner Powell
Commissioner Tristani
Ari Fitzgerald
Adam Krinsky
Mark Schneider
Peter Tenhula
Bryan Tramont
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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC

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OFFICE OF THE SECRETARY

In the Matter of	)	
	)	
Service Rules for the 746-764 and	)	WT Docket No. 99-168
776-794 MHz Bands, and Revisions	)	
Revisions to Part 27 of the Commission's	)	
Rules	)	

To the Commission:

COMMENTS OF FREESPACE COMMUNICATIONS

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Charles W. Logan
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Counsel for FreeSpace Communications

January 18, 2000

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Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC

In the Matter of	)	
	)	
Service Rules for the 746-764 and 776-794 MHz Bands, and Revisions Revisions to Part 27 of the Commission's Rules	))))	WT Docket No. 99-168

To the Commission:

COMMENTS OF FREESPACE COMMUNICATIONS

I. INTRODUCTION AND SUMMARY

FreeSpace Communications (FreeSpace) hereby submits these comments in response to the Public Notice issued on January 7, 2000 in this proceeding.[1] The Public Notice seeks comment on the technical and operational requirements the Commission should establish in 6 MHz of "guard band" spectrum to protect adjacent-band public safety communications.

Consistent with its previous filings in this proceeding, FreeSpace sets forth in these comments a range of specific technical requirements that will protect current and future public safety communications against interference from commercial licensees operating in the guard bands. Indeed, the Association of Public-Safety Communications Officials International, Inc. (APCO) has stated that FreeSpace's proposal "would provide

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[1] "Public Comment Sought on Issues Related to Guard Bands in the 746-764 MHz and 776-794 MHz Spectrum Block," WT Docket No. 99-168, DA 00-31 (released Jan. 7, 2000) (Public Notice).

effective interference protection."[2] The technical requirements described below obviate any need for the Commission to impose restrictions on the types of services or system architecture that can be offered in the guard bands. FreeSpace is committed to working with the Commission and the public safety community in developing service-neutral technical rules -- whether it be FreeSpace's proposal or an effective alternative -- that will provide strong interference protection for public safety communications.

By adopting these requirements or similar service-neutral rules, the Commission would permit any interested party willing and able to abide by these rules to bid for the guard band spectrum.[3] This would promote the "efficient and intensive use of this spectrum," a goal that underlies the Commission's *First Report and Order* in this

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[2] Letter of Joe Hanna, President of APCO, to Chairman Kennard, WT Docket No. 99-168 (filed Dec. 27, 1999).

[3] FreeSpace emphasizes that there may be alternative sets of technical rules that the Commission and public safety community may determine also provide effective protection for public safety systems. For example, the public safety community has indicated that it may be possible to permit higher power systems, subject to more relaxed out-of-band emissions limits, to operate in the guard bands provided they comply with frequency coordination procedures that ensure that base stations in such systems are deployed outside the environment in which public safety mobile units operate. Letter of Robert Gurss, Counsel for APCO, WT Docket No. 99-168 (filed Jan. 4, 2000). If the Commission and the public safety community are satisfied that such an approach will protect public safety operations, the Commission could adopt two sets of rules for guard band operations. One set could take the FreeSpace approach, with stringent out-of-band emissions and power limits as well as frequency coordination procedures. The other set would permit more relaxed power and emissions limits but place strict limits on base station deployment. The winning bidder in the auction of the guard bands would then, in its long-form license application, select the set of rules under which it would be required to operate. This would provide maximum flexibility in auctioning and licensing this spectrum, and would not involve restrictions on the type of services that can be offered in this spectrum.

proceeding.[4] It is also consistent with the *First Report and Order*'s effort to avoid adopting service rules that establish particular service configurations, and to harness "marketplace forces, operating through the auction process, rather than regulatory fiat, [to] determine which of the multitude of service proposals will actually be implemented."[5] The Commission should take this same approach in establishing rules for the guard bands and let any interested party bid for the entire 6 MHz of guard band spectrum regardless of the type of commercial service it plans to offer in these bands.

By promoting open auctions and the most efficient use of the guard bands, the Commission would pursue the policies that underlie the *First Report and Order*. In particular, the guard band spectrum offers the exciting potential to promote new, innovative wireless broadband services. These services can greatly benefit consumers, including those that live in rural areas and on tribal lands. The Commission should craft service-neutral technical rules for the entire 36 MHz of commercial spectrum, including the guard bands, that promote these benefits.

The Commission should reject proposals by the private radio industry that run directly contrary to these objectives. These parties ask the Commission to employ "regulatory fiat" and dictate that the guard band spectrum can only be used for private radio uses, thus severely limiting the number of potential bidders private radio users would have to compete against in an auction for this spectrum. This proposed exclusive private radio set-aside is arbitrary, anticompetitive, contrary to the statutory requirement

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[4] *First Report and Order* in WT Docket No. 99-168, FCC 00-5, ¶ 15 (released Jan. 7, 2000) (*First Report and Order*).

[5] *Id.* at ¶¶ 15, 31.

that this spectrum be allocated for "commercial use," and would flout the Commission's objective of promoting "efficient and intensive use of spectrum resources [that] is critical to facilitating new wireless technologies that have the potential to provide innovative new services and, as well, to serve underserved areas with both narrowband and broadband services."[6]

II. FREESPACE'S PROPOSED TECHNICAL REQUIREMENTS WILL ENSURE THAT COMMERCIAL LICENSEES OPERATING IN GUARD BANDS WILL PROTECT PUBLIC SAFETY COMMUNICATIONS FROM INTERFERENCE.

As the Commission has recognized, it has a strong statutory mandate to ensure that commercial licensees operating in the 746-764 and 776-794 MHz bands (commercial bands) do not cause harmful interference to public safety services operating in adjacent 764-776 MHz and 794-806 MHz bands (public safety bands).[7] Consistent with this mandate, the *First Report and Order* established two paired guard bands -- one of 4 MHz and one of 2 MHz -- located immediately adjacent to the public safety bands.[8]

1. *FreeSpace Supports the Establishment of Strong Interference Safeguards Governing Guard Band Operations.*

FreeSpace has supported such a guard band approach, and has consistently supported the adoption of clear, enforceable rules that ensure that commercial licensees

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[6] *Id.* at ¶ 18.

[7] *Id.* at ¶ 33. *See* 47 U.S.C. § 337(d)(4); Balanced Budget Act of 1997, Conference Report to Accompany H.R. 2015, 105th Cong., 1st Sess., Report 105-217, at 580 (July 30, 1997).

[8] *First Report and Order* at ¶¶ 3, 33. The guard bands will be located at 746-747 MHz, 762-764 MHz, 776-777 MHz, and 792-794 MHz.

operating in the guard bands protect public safety communications from interference.[9] In the *First Report and Order*, at ¶ 3, the Commission stated that "we intend to adopt more stringent interference protection standards for these Guard Bands than we adopt in this Report and Order for the larger segments that do not directly abut public safety spectrum." FreeSpace's proposed rules meet this objective.

FreeSpace has stated throughout these proceedings that the guard bands are well-suited for low power commercial services that provide greater protection to public safety than high power services that would operate in the remaining 30 MHz of the commercial bands. As set forth in Appendix A to these comments, a more strict power limit is necessary in the guard band spectrum precisely due to the guard bands' proximity to the public safety bands. A high power system operating on frequencies that are right next to public safety mobile receive channels can overload the front-end of the public safety receiver or mix with spectral impurities of the first local oscillator of a public safety receiver to produce interference at the first intermediate frequency of the receiver. For these reasons, FreeSpace has argued for a power spectral density limit of 4 mW/kHz to apply to the three guard bands that abut the public safety bands.

In addition, FreeSpace has supported, and continues to support, a more stringent out-of-band emissions limit for guard band operations compared to the limits imposed on the remaining 30 MHz of the commercial bands. As detailed in Appendix A, this is a result of the strict power limits that are necessary to impose on guard band operations to protect public safety communications. Systems operating with lower power limits tend to

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[9] Letter of Ruth Milkman, Lawler, Metzger & Milkman, to Thomas Sugrue, Chief, Wireless Telecommunications Bureau, WT Docket No. 99-169 (filed Oct. 13, 1999).

have smaller sized cells. Smaller cells promote the efficient use of scarce spectrum resources through more frequent spatial reuse. However, achieving wide area coverage also requires proportionately more cells, therefore providing more potential opportunities for interference, *unless* out-of-band emissions limits are adjusted accordingly to compensate for the increased number of cells. Thus, stronger out-of-band emissions limits are necessary in the guard bands compared to the other 30 MHz, where high power systems can operate with larger cells.

Strict power limits and out-of-band emissions limits permit the guard bands to be used for commercial services while providing strong interference protection to public safety communications. In addition, FreeSpace supports the use of frequency coordination procedures by guard band licensees to provide additional protection to public safety operations. In the following section, FreeSpace proposes a set of specific power and out-of-band emissions limits as well as frequency coordination procedures to protect public safety systems from interference.

2. *FreeSpace's Proposed Requirements for Guard Band Licensees Will Provide Effective, Enforceable Interference Protection for Public Safety Operations.*

FreeSpace has worked closely with the public safety community throughout this proceeding to develop specific requirements to ensure that guard band licensees protect public safety communications from interference, and, as a result, has modified its proposed technical requirements for guard band operations to address potential interference concerns. FreeSpace has also agreed with APCO that its proposed technical requirements for guard band operations should be incorporated into enforceable Commission rules that would apply to guard band commercial licensees, whether it be FreeSpace or any other winning bidder.

FreeSpace therefore proposes the following specific technical and operational requirements for commercial licensees operating in the guard bands. These proposed requirements are consistent with FreeSpace's previous filings in this proceeding.[10] Although there may be other service-neutral means of protecting public safety communications,[11] these proposed requirements provide very effective public safety interference protection. They are clear, enforceable, and would require all commercial systems operating in the guard bands, whether they are operated by FreeSpace or some other party, to protect current and future public safety services from interference. They achieve this goal without imposing service or network-architecture restrictions, and thus further the Commission's goal of "provid[ing] further protection for public safety bands and ... encourag[ing] the effective and valued use of the Guard Band spectrum."[12]

In particular, FreeSpace proposes the following requirements for commercial licensees operating in the guard bands. For each proposed rule, we offer a succinct rationale for why the rule should be adopted. A more detailed technical rationale concerning the proper power limits and out-of-band emissions limits are set forth in the attached Appendices. To simplify references to the guard bands, we number them from one to four in order of increasing frequency, *i.e.*, 746-747 MHz: guard band one; 762-764 MHz: guard band two; 776-777 MHz: guard band three; and 792-794: guard band four.

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[10] *See, e.g.*, Letter of Charles Logan, Lawler, Metzger & Milkman, to Magalie Roman Salas, FCC Secretary, WT Docket No. 99-168 (filed Dec. 17, 1999).

[11] *See, e.g.*, *supra*, note 3.

[12] *First Report and Order* at ¶ 34.

1.0 Out-of-Band Emissions Limits

Rule 1.1: Out-of-band emissions of fixed and mobile transmitter units in any guard band must *at least* be attenuated below the full-bandwidth transmitter power by a factor of not less than 43 +10 log (P) decibels anywhere outside the guard band, as measured in a 30 kHz bandwidth, where P is the full-bandwidth transmitter power in watts.

Rationale: This rule imposes the *minimum* required out-of-band emissions limit for guard band operations. Additional rules below specify more stringent emissions limits for the special protection of public safety operations in the 764 – 776 MHz and 794 – 806 MHz bands.

Rule 1.2: Out-of-band emissions of fixed transmitter units in guard bands two and three must be attenuated below the full-bandwidth transmitter power by a factor of not less than 87 +10 log (P) decibels on all frequencies between 764 MHz and 776 MHz, as measured in a 6.25 kHz bandwidth, where P is the full-bandwidth transmitter power in watts.

Rationale: FreeSpace has filed a detailed technical analysis describing the derivation of this limit;[13] it is attached to these comments as Appendix B. APCO has previously stated that this out-of-band emissions limit "is superior to all other proposals."

Rule 1.3: Out-of-band emissions of mobile and portable transmitter units in guard band four must be attenuated below the full-bandwidth transmitter power by a factor of not less than 65 +10 log (P) decibels on all frequencies between 794 MHz and 806 MHz, as measured in a 6.25 kHz bandwidth, where P is the full-bandwidth transmitter power in watts.

Rationale: This level of attenuation will provide effective protection against any harmful out-of-band emissions from mobile or portable units. In addition, Rule 1.4, described below, provides additional protection against mobile-to-mobile and base-to-base interference.

Rule 1.4: The second and third guard bands are designated for fixed transmitter units only. The fourth guard band is designated for mobile transmitter units only. The first guard band is designated for either mobile or fixed transmitter units.

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[13] Letter of Charles Logan, Lawler, Metzger & Milkman, to Magalie Roman Salas, WT Docket No. 99-168 (filed Dec. 16, 1999).

Rationale: The second and third guard bands lie adjacent to the public safety mobile receive band. Thus, mobile unit transmissions in these two guard bands should be disallowed to prevent mobile-to-mobile interference. Similarly, the fourth guard band is adjacent to the public safety base receive band. Thus, fixed unit transmissions should be disallowed in the fourth guard band to prevent base-to-base interference. The first guard band does not pose an interference threat to public safety units because it is not adjacent to any public safety bands. Therefore, for maximum flexibility, the rules should permit either fixed or mobile units to transmit in this band. These guard band designations have the benefit that the guard bands can accommodate either symmetric (*e.g.,* voice) or asymmetric (*e.g.,* internet) services. For symmetric services, the licensee would pair guard bands one and three and pair guard bands two and four, each with a single base transmit band and a single mobile transmit band; in short, a symmetric arrangement. For asymmetric services, an aggregation of all four guard bands would provide for three base transmit bands and a single mobile transmit band.[14]

2.0 Frequency Coordination Requirements

Rule 2.1: The guard band licensee shall be required to develop frequency coordination procedures in cooperation with the designated public safety frequency coordinator in order to protect public safety operations. Guard band licensees shall be required to cooperate with public safety to resolve any interference concerns through mutually satisfactory arrangements.

Rationale: By embracing frequency coordination as an effective technique to avoid and resolve interference concerns, this rule would ensure that the public safety community has an integral, essential, ongoing role in developing procedures that achieve the desired protection.

Rule 2.2: The guard band licensees shall be required to develop and maintain a centralized database identifying the "real time" location (*e.g.*, via GPS) and operating frequencies of all base stations. Public safety frequency coordinators shall have access to this database.

Rationale: Such a database would be an important component enabling efficient coordination between guard band licensees and public safety frequency coordinators. Detailed knowledge of the location and frequencies of all base stations will aid in the diagnosis and elimination of any interference

[14] For this reason, and to ensure viable commercial operations in the guard bands, the Commission should permit parties to bid on all 6 MHz of guard band spectrum.

concerns that may arise, and facilitate the coordination of site placements between public safety and the guard band licensees.

Rule 2.3: The guard band licensee shall be required to maintain centralized, dynamic control over the operation and frequency use of each of its base stations.

Rationale: It is important for guard band licensees to be able to respond rapidly in the event that interference arises. With network control over the operation and frequency use of the base stations, the licensee can quickly eliminate specific interference problems as required by applicable coordination agreements.

Rule 2.4: Fixed transmitter units in guard bands two and three and mobile units in guard band four shall operate so that their first adjacent channel emissions are contained entirely within the guard bands and therefore fall outside the adjacent public safety bands.

Rationale: A major concern of the public safety community is the threat of adjacent channel emissions that may spill over into the public safety mobile receive band and interfere with public safety systems operating at or near the band edge. To address this concern, APCO has recommended the adoption of a requirement that guard band licensees reconfigure the frequency use of their base and mobile units to prevent adjacent channel interference (assuming "worst-case scenario" conditions).[15]

FreeSpace believes the above rule would be one way of implementing this recommendation in the form of a specific, effective rule to prevent adjacent-channel interference. It would essentially require the guard band licensee to "back off" from using the frequencies at the band edge. As a consequence, the licensee's adjacent channel emissions would remain exclusively within the guard band while permitting flexibility in the selection of channel bandwidths. This approach would create an effective buffer zone between guard band channels and public safety channels near the band edge that would prevent adjacent channel emissions from the guard band systems from causing interference. While the same effect may be achieved in practice through compliance with stringent out-of-band emissions limits, the above rule provides greater assurance that, no matter what out-of-band emissions limits are adopted, no adjacent-channel interference will be caused.

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[15] Letter of Robert Gurss, Counsel for APCO, WT Docket No. 99-169 (filed Jan. 4, 2000).

Rule 2.5: The guard band licensee shall be required to operate a 24-hour, 7-day per week, toll-free hotline for the purpose of providing rapid response to interference concerns that may arise in the field and resolving such concerns according to the coordination agreements in force. Should interference arise, the guard band licensee shall cease operation on the offending frequency channels immediately until the problem is fixed.

Rationale: This rule further ensures the timely responsiveness of the guard band licensee in the event that interference arises.

3.0 Transmit Power Limits

Rule 3.1: The transmit power spectral density of fixed units operating in guard bands two and three and mobile units operating in guard band four shall be restricted to 4mW/kHz, as delivered into the input of the transmit antenna, with an antenna gain of up to 6dBi. For antenna gains above 6dBi, the transmit power shall be reduced by 1dB for every 1dB by which the antenna gain exceeds 6dBi. This power spectral density limit shall not apply to units operating in guard band one, which shall be subject to the power limits that apply to the remaining 30 MHz of the commercial bands.

Rationale: The proposed out-of-band emissions limits protect against interference power that falls directly in the victim receiver's channel. Proposed rule 3.1 protects against a different interference mode. Specifically, the proposed rule prevents the operation of a high-power transmitter on frequencies that are close to those used by sensitive public safety receivers. Such a scenario would overload the front end of the receiver or cause interference due to blocking or reciprocal mixing. The proposed power limit in this rule would prevent this from happening. Should the Commission prefer to state this rule in terms of ERP rather than power spectral density, FreeSpace recommends that transmissions be limited to 5W ERP, which would be consistent with the above rule for a channel bandwidth of 500kHz.

Rule 3.2: Units transmitting in guard bands two, three and four shall operate in such a way as to eliminate any possibility of the aggregate transmit power spectral density of several such units from exceeding the limits specified in Rule 3.1 for a single unit.

Rationale: This proposed rule effectively would impose a limit on maximum power spectral density in a given guard band in order to prevent the aggregation of power from multiple units that could potentially exceed this limit.

Rule 3.3: When transmitting in guard bands two, three and four, guard band units shall be required to incorporate active power control mechanisms to minimize the average transmit power in those bands.

Rationale: In the past, active power control has been used effectively to reduce the probability of interference. This is simply because interference is less likely when transmitters operate on the minimum required transmit power for successful communications.

Collectively, these measures would protect public safety mobile and base unit operations against harmful interference. Indeed, these measures provide greater protection than the proposals to restrict the guard bands to high-powered, wide-area PMRS systems. The combination of a low-power system with strict out-of-band emissions limits coupled with frequency coordination between the commercial provider and public safety systems would establish superior technical rules to ensure that public safety communications are interference free.[16] Although these safeguards clearly would provide effective protection, FreeSpace also is committed to working with the Commission and the public safety community in crafting alternative proposals or modifications that they may recommend.

3. *FreeSpace Is Not Asking The Commission To Endorse Its Technology, Only To Set Service-Neutral Technical Rules That Allow All Interested Parties To Bid For The Guard Bands.*

In their self-serving efforts to have the Commission set-aside the guard band for private radio uses only, Motorola and the private radio industry have sought to confuse the issues by introducing a red herring. Specifically, these parties allege that the Commission should bar FreeSpace from bidding for the guard band spectrum because its

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[16] With these strong interference measures, public safety systems in the 700 MHz band would not encounter the incidents of interference that have arisen in the 800 MHz band between commercial and public safety operations.

technology is "a novel, untested system."[17] This amounts to a request by Motorola and private radio parties that the Commission determine "by regulatory fiat" the permissible uses of the guard band spectrum, rather than allowing "marketplace forces, operating through the auction process," to make that determination.[18] Moreover, the "novelty" of FreeSpace's technology is, in a word, irrelevant. In our view, the Commission's responsibility is not to endorse any particular technology or service, but to establish service-neutral technical rules that provide effective protection for public safety and give all interested parties, not just the private radio community, the opportunity to bid in the auction of the guard band spectrum.

FreeSpace's proposed technical rules for the guard bands do just that. They would impose generally applicable technical requirements on FreeSpace or any commercial licensee in the guard band. They are not tied to FreeSpace's technology, nor are they, as Motorola seeks to claim, "craft[ed] ... for one company rather than a service."[19] They set forth power limits, out-of-band emissions limits, and specific frequency coordination procedures. In sum, they are clear, concrete rules to which *any* commercial guard band licensee would be required to adhere to protect public safety services.

The arguments of Motorola and private radio parties also fly in the face of the well-established Commission policy of encouraging innovative new technologies and

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[17] Letter of Leigh Chinitz, Motorola, WT Docket No. 99-168, at 4 (filed Jan. 5, 2000). *See also* Letter of Mark Crosby, ITA, and Mary McDermott, PCIA, WT Docket No. 99-168 (filed Jan. 4, 2000).

[18] *First Report and Order* at ¶ 31.

[19] Letter of Leigh Chinitz, Motorola, WT Docket No. 99-168, at 4 (filed Jan. 5, 2000).

services. The *First Report and Order* in this proceeding seeks to promote this policy, stating the "efficient and intensive use of spectrum resources is critical to facilitating new wireless technologies that have the potential to provide innovative new services and, as well, to serve underserved areas with both narrowband and broadband services."[20] New technologies should be promoted, not victimized by self-interested and unfounded speculation by established spectrum users seeking to manipulate the Commission's rules to let them accumulate yet more spectrum at below-market prices.

III. FREESPACE'S PROPOSED TECHNICAL REQUIREMENTS ARE SUPERIOR TO THE OTHER PROPOSALS IN THIS PROCEEDING.

No party in this proceeding has advocated that the guard bands go unused. The *First Report and Order* recognized this, stating that "[w]hile protecting adjacent public safety bands from harmful interference, the sub-bands we establish here will allow for effective and valued use of the spectrum, consistent with sound spectrum management, rather than the creation of Guard Band spectrum of little use."[21]

The relevant question in assessing a party's guard band proposal is how it compares with competing proposals to prevent interference to public safety. The FreeSpace proposal not only provides clear and effective interference protection, but also is superior to other guard band proposals advanced in this proceeding.

Motorola and the private radio industry have proposed that the guard bands be limited to private radio uses that would be deployed through a new concept called a

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[20] *First Report and Order* at ¶ 18.

[21] *Id.* at ¶ 34.

"band manager" and would be subject to frequency coordination procedures as well as out-of-band emissions and power limits. FreeSpace has shown in a previous filing in this proceeding[22] that its guard band plan offers superior protection for public safety communications. FreeSpace's proposal would require guard band licensees to comply with very strict power limits that would ensure that the licensee's transmit power is never more than a few watts. These limits are far more stringent than Motorola's proposal, which would permit PMRS base stations to transmit between 65W and 1000W ERP depending on antenna height and PMRS mobiles to operate with 30W maximum output power. FreeSpace's proposed out-of-band emissions limits are also far more stringent than Motorola's proposal; indeed, FreeSpace's proposed limits represent an increase in attenuation of 37dB over Motorola's proposed PMRS emissions limits.

FreeSpace recognizes that, in addition to stating that FreeSpace's proposal provides effective protection, APCO has stated that the private radio guard band proposal would be effective in protecting public safety systems through frequency coordination.[23] APCO's letter further states that the more lenient out-of-band emissions limits proposed for PMRS guard band users "is offset by the spatial attenuation inherent in a system design that places [PMRS] base stations outside the immediate environment in which [public safety] mobile units are operating."[24] As set forth in FreeSpace's previous

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[22] Letter of Charles Logan, Lawler, Metzger & Milkman, to Magalie Roman Salas, WT Docket No. 99-168 (filed Dec. 23, 1999).

[23] Letter of Robert Gurss, Counsel for APCO, to Magalie Roman Salas, WT Docket No. 99-168 (filed Jan. 4, 2000).

[24] *Id.* at 2.

filings,[25] however, it is unclear whether this assumption will hold true in all instances. Indeed, the "band manager" may very well have a strong incentive to deploy as many PMRS systems as possible to maximize its revenues.

It is also important to keep in mind that PMRS deployment in the guard bands would most likely take place well before public safety systems are deployed in the adjacent public safety bands. In effect, PMRS systems would be licensed in the guard bands without any public safety systems to coordinate against for a significant period of time. The result could be the creation of a high density PMRS emissions environment in the guard bands that would pose a threat to public safety systems given the more lenient PMRS out-of-band emissions that have been proposed. Given these considerations, FreeSpace's proposal of very strict out-of-band emissions and power limits, as well as frequency coordination, is superior to Motorola's proposal in terms of protecting both current *and* future public safety systems.

It is also instructive to analyze FreeSpace's proposed guard band requirements within the context of the technical rules the Commission has adopted for the remaining 30 MHz of the commercial bands. Commercial system base and mobile units operating in this 30 MHz have the potential to cause interference to public safety systems even though they are not operating in immediately adjacent spectrum bands. This is why the Commission has imposed out-of-band emissions limits and other technical requirements on these commercial systems. Although, as stated above, guard band licensees should be subject to more stringent requirements given that they are immediately adjacent to the public safety bands, the rules that apply to commercial systems operating in the 30 MHz

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[25] Letter of Charles Logan, Lawler, Metzger & Milkman, to Magalie Roman Salas,

provide a useful frame of reference. In particular, they provide a benchmark for the Commission's assessment of the appropriate level of public safety interference protection. FreeSpace believes its proposed guard band requirements compare very well against this benchmark even after taking into account the need to impose more stringent technical limits on guard band operations.

IV. THE COMMISSION SHOULD NOT IMPOSE RESTRICTIONS ON THE TYPES OF SERVICES OR SYSTEM ARCHITECTURES THAT CAN BE OFFERED IN THE GUARD BANDS.

The Public Notice asks whether the Commission should "restrict operation in the guard bands to those entities that would not use an architecture that employs an intense cellular-like frequency re-use pattern." As we show below, such restrictions are unnecessary and contrary to established Commission policies and therefore should be rejected.

1. *Service or Architecture Restrictions Are Unnecessary to Protect Public Safety Communications.*

As described above, the Commission can establish specific technical requirements for guard band operations that would provide effective interference protection for public safety communications without imposing restrictions on the types of services or system architectures that could be used in the guard bands. The range of requirements FreeSpace has proposed -- stringent out-of-band emissions limits and power limits as well as effective frequency coordination procedures -- demonstrate this fact.

WT Docket No. 99-168 (filed Dec. 23, 1999).

2. *Restrictions on System Architectures Are Difficult if Not Impossible to Define and Enforce.*

Not only are restrictions on system architectures unnecessary, it is unclear how the Commission would define and enforce such limitations. What system architectures would the Commission categorize as using "an intense, cellular-like frequency re-use pattern" and which ones would fall outside this amorphous category? It is not at all clear why private radio band managers would not conceivably fall in this category. Indeed, in order to maximize their revenues, band managers may very well seek to deploy private radio systems in an intensive pattern that employs frequency re-use techniques. They would have a substantial opportunity to do so since public safety systems are most likely years away from being deployed in the adjacent public safety bands.

Imposing restrictions on system architectures in the guard would result in uncertain and arbitrary rules governing the guard bands. The Commission should instead employ well-established measures for preventing interference to current *and* future public safety systems, such as out-of-band emissions and power limits and frequency coordination procedures. The Commission has, particularly in recent years, strived to employ these measures to provide effective interference protection *without* imposing restrictions on system architectures, thereby promoting the efficient use of the spectrum.

3. *System Architecture Restrictions Will Prevent the Most "Efficient and Intensive Use of Spectrum Resources."*

The *First Report and Order* emphasizes the importance of promoting the "efficient and intensive use of spectrum resources."[26] This is especially important given the propagation characteristics of the spectrum bands at issue here. As the Commission

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[26] *First Report and Order* at ¶¶ 15, 18.

observed in that order,[27] "efficiency is especially important because of the band's suitability for uses ranging from wideband mobile communications to innovative, fixed wireless Internet access services and new broadcast-type services."

Service or architecture restrictions are inconsistent with these important objectives and would, in fact, undermine them. Cellular systems and frequency re-use help to maximize the "efficient and intensive use" of the spectrum. The reason is quite straightforward: the use of cellular architectures, especially smaller cells, permits the re-use of the same spectrum band from cell to cell. This greatly increases the capacity, and efficiency, of the wireless network employing such a system. Prohibiting licensees from taking advantage of these efficiencies would be flatly contrary to sound spectrum management and would not serve any public interest goal.

Service or architecture restrictions would also deprive consumers of enormous benefits that would result from the most innovative and highest valued use of the guard bands. The *First Report and Order* states that the "record in this proceeding demonstrates diverse and substantial demand for expanded wireless broadband spectrum -- for uses ranging from the implementation of next generation applications as extensions of existing mobile and fixed uses, to the implementation of various innovative stand-alone technologies."[28] The Commission also notes the importance of promoting high-

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[27] *First Report and Order* at ¶ 18.

[28] The Commission even cites FreeSpace's October 13 filing in this proceeding to support this point. *First Report and Order* at ¶ 18, n.49.

speed wireless internet access as a competitive alternative to digital subscriber line (DSL) and cable modem services, as well as extending these services to underserved areas.[29]

Adopting a flexible services rules, without restrictions on services or system architectures, would promote these public interest goals. FreeSpace is an example of the type of company that, if permitted, would bid for the guard band spectrum to provide consumers innovative new services. As set forth in its previous filings, FreeSpace has developed a system that would provide consumers inexpensive, high-speed access to the internet on a nationwide basis.[30] Its system is ideally suited for rural and underserved areas. Indeed, over 15 Tribal Nations have written the Commission urging it to give entrepreneurs, such as FreeSpace, a chance to bid on the guard bands so that they can provide innovative services to underserved areas.[31]

In sum, the Commission should reject proposals to restrict the services or system architectures operating in the guard band spectrum. They are not necessary to protect public safety systems, and they would prevent the most efficient use of the guard band spectrum and the substantial consumer benefits that come with such efficient use.

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[29] *Id.* at ¶¶ 4, 18.

[30] Letter of Ruth Milkman, Lawler, Metzger & Milkman, to Thomas Sugrue, WT Docket No. 99-168 (Oct. 13, 1999).

[31] The following representatives of Tribal Nations have submitted letters to the FCC: the Montana-Wyoming Tribal Leaders Council, the Blackfeet Nation, the Penobscot Indian Nation, the Mandan, Hidatsa and Arikara Nations, Pokagon Band of Potawatomi Indians, the Mashantucket Pequot Tribal Nation, and the Sealaska Corporation.

V. THE COMMISSION SHOULD REJECT PROPOSALS TO SET-ASIDE THE GUARD BANDS FOR EXCLUSIVE PRIVATE RADIO USE.

Motorola, Inc. and parties representing the private radio industry have proposed that the Commission set-aside the guard bands for exclusive private radio use.[32] Under their proposal, only private radio "band managers" would be eligible to bid in the auction for this spectrum, and its use would be limited to private radio services. These parties claim that only such a private radio set-aside will protect public safety systems from interference.

As we have shown above, this claim is simply groundless. Indeed, in a recent letter to the Commission, APCO expressly stated that it "believes that both the FreeSpace and private wireless proposals have merit, and both are worthy of Commission consideration."[33] Further, as explained above, FreeSpace's proposed technical rules, which include far stronger out-of-band emissions and power limits, are superior to the private radio proposal.

Not only is a private radio set-aside unnecessary to protect public safety, it is inconsistent with the Commission's goals of making spectrum markets more efficient and promoting flexible service rules. The Commission emphasized the importance of these goals in the *First Report and Order*, as well as in its recent *Spectrum Reallocation Management Policy Statement*.[34] Flexible service rules, *not* private radio set-asides,

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[32] *See* Comments of Motorola at 12-13; Comments of Industrial Telecommunications Association (ITA); Comments of United Telecom Council (UTC).

[33] Letter of Joe Hanna, President of APCO, to Chairman Kennard, WT Docket No. 99-168 (filed Dec. 27, 1999).

[34] *First Report and Order* at ¶ 16; *Spectrum Reallocation Policy Statement*, FCC 99-354 (released Nov. 22, 1999).

promote spectrum efficiency by ensuring that the spectrum is put to its highest valued use. This, in turn, promotes technological innovation and consumer benefits.[35] If private radio interests can provide these benefits because they have the highest value use of the spectrum, they will win the licenses in the auction.

In addition to undermining these well-established Commission policies, a private radio set-aside would be inconsistent with the Commission's 1998 decision reallocating these spectrum bands. The Commission there rejected a proposal to allocate spectrum in these bands exclusively to private radio services.[36] The Commission should do the same here.

The proposed "band manager" concept does not change this analysis. The Commission sought comment in the *Notice of Proposed Rulemaking* in this proceeding on the possibility of a band manager bidding on spectrum in this band in order to sublicense the spectrum to private radio users.[37] Private radio parties have urged the

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[35] *Implementation of Section 309(j) of the Communications Act -- Competitive Bidding*, 9 FCC Rcd 2348, ¶ 5 (1994). *See also Improving Commission Processes*, 11 FCC Rcd 14006, 14010 (1996); G. Rosston and J. Steinberg, *Using Market-Based Spectrum Policy to Promote the Public Interest*, OPP Working Paper No. (1997) (*reprinted in* vol. 50, no. 1, of the Federal Communications Law Journal); Evan Kwerel & Alex D. Felker, *Using Auctions to Select FCC Licenses*, OPP Working Paper No. 16 (1985); Thomas G. Krattenmaker & Lucas A. Powe, Jr., *Regulating Broadcast Programming* 53 (1994); Declaration of Gregory L. Rosston, submitted with Comments of Nextel Communications filed Sept. 30, 1999 in WT Docket No. 99-87 (Rosston Declaration).

[36] *Reallocation of Television Channels 60-69, the 746-806 Band*, 12 FCC Rcd 22953, ¶ 20 (1998).

[37] *Notice* at ¶ 15.

Commission to test the band manager concept, which they characterize as "a new and innovative approach to spectrum management."[38]

The Commission, however, should not allow the band manager concept to be used to exclude commercial licensees from the auction by limiting the permissible uses and services that can be offered in the guard bands. The private radio industry's band manager proposal boils down to a transparent effort to limit artificially the number of potential auction bidders in order to benefit the private radio industry. This is not a test of a "new and innovative approach to spectrum management." Rather, the proposal amounts to an effort to lower the amount of money the private radio industry would have to bid for the guard band spectrum. If these parties truly want to test the band manager concept, they should compete against other licensees in an open auction.

Finally, as FreeSpace previously has demonstrated,[39] setting aside the guard bands for exclusive private radio use would be contrary to section 337(a) of the Communications Act, as amended. In particular, section 337(a) explicitly directs the Commission to allocate the 746-764 and 776-794 MHz bands, which include the guard bands at issue here, "for commercial use ...." [40] In the context of wireless services, both Congress and the Commission have long used the term "commercial" services or uses to distinguish such services from "private" services, such as private land mobile.

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[38] Letter of Mark Crosby, Industrial Telecommunications Association, and Mary McDermott, Personal Communications Industry Association, WT Docket No. 99-168 (filed Jan. 4, 2000).

[39] *See* Letters of Ruth Milkman, Lawler, Metzger & Milkman, to Thomas Sugrue, Chief, Wireless Telecommunications Bureau, WT Docket No. 99-168 (filed Oct. 13, 1999 and Oct. 27, 1999).

[40] 47 U.S.C. § 337(a)(2).

Significantly, Congress drew such a distinction in the legislative history of the Balanced Budget Act of 1997, which enacted section 337(a).[41] Even Motorola, in advocating a private radio set-aside, has acknowledged the distinction between commercial and private services.[42]

Setting aside the guard bands for exclusive private radio use would consequently violate the clear statutory requirement that this spectrum be allocated for commercial use. For this reason, a wide range of parties have opposed a private radio set-aside in this proceeding, including the Cellular Telecommunications Industry Association, Microsoft Corporation, Intel Corporation, AT&T Wireless Services, Inc., US West, the Association for Maximum Services Television, Ericsson Inc, Excite@Home, and Nextlink Communications, Inc. The Commission should therefore open the bidding for the guard bands to all entities that are willing and able to comply with service-neutral rules that will protect public safety communications from interference.

VI. CONCLUSION

The Commission should establish strong technical rules for the guard band to protect public safety communications against interference. It can do so without imposing restrictions on the type of services or system architectures that can be offered in the guard bands. By taking a service-neutral approach, the Commission fulfills its statutory

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[41] H. Conf. Rep. No. 105-217, 105th Cong., 1st Sess. 575-76 (1997) (*reprinted in* 1997 U.S. Code Cong. & Admin. News 176, 196).

[42] Letter of Steve B. Sharkey of Motorola, Inc. to Magalie Roman Salas, FCC Secretary, Oct. 18, 1999 ("Under Motorola's plan, the majority of the 36 MHz would be available for *commercial services*. A portion of the spectrum would, however, be made available, through auction, to *private services*.") (emphasis added).

mandate not only to protect public safety communications, but also to ensure that the guard band spectrum is available to innovative commercial services that can greatly benefit consumers.

Respectfully submitted,

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A

Appendix A

Technical Requirements for the "Guard Bands"

The Commission has established technical rules for the operation of commercial systems in the 747 – 762 MHz and 777 – 792 MHz bands ("30 MHz commercial bands") in the *First Report and Order*. The Commission has sought additional comment on the appropriate technical rules for the 746 – 747 MHz, 762 – 764 MHz, 776 – 777 MHz and 792 – 794 MHz bands ("Guard Bands"). FreeSpace Communications (FreeSpace) has proposed a number of technical service rules for the purpose of protecting Public Safety systems operating in the 764 – 776 MHz and 794 – 806 MHz bands ("public safety bands"). In this appendix, FreeSpace provides detailed technical rationale in support of its proposed rules, which are more stringent than the technical rules the Commission has adopted for the 30 MHz commercial bands .

Background

In the *First Report and Order*, the Commission established both transmit power limits and out-of-band emissions (OOBE) limits for systems operating in the 30 MHz commercial bands. In particular, the Commission adopted the limits summarized in Table 1 below.

Table 1. Commercial Service Rules Summary

Unit	Frequency Band	Transmit Power	OOBE
Fixed	747 – 762 MHz	1000 W ERP	76 + 10 log(P)
Mobile	777 – 792 MHz	30 W ERP	65 + 10 log(P)
Portable	777 – 792 MHz	3 W ERP	65 + 10 log(P)

When considering the appropriate service rules for commercial systems operating in the guard bands, we begin with the rules that the Commission has deemed appropriate and sufficient for commercial systems in the commercial bands as a starting point. In

addition, we note that the Commission in the *First Report and Order*, at ¶ 3, stated that "we intend to adopt more stringent interference protection standards for these Guard Bands than we adopt in this Report and Order for the larger segments that do not directly abut public safety spectrum."

Transmit Power Limits

The only essential difference between the guard bands and the commercial bands is the direct proximity in frequency of the guard bands to the public safety bands. This prompts us to ask the very simple question: given particular transmit power and OOBE restrictions, does increased proximity in frequency *alone* cause the interference to public safety systems to increase? If so, then what technical rules are appropriate to compensate for the increased interference?

To answer this question, we focus on interference modes that become more difficult to eliminate with reduced frequency separation between an offending transmission and a victimized receiver. There are two interference modes that are more difficult to reject as the frequency separation is reduced: receiver front-end overload, and receiver desensitization by reciprocal mixing with first local oscillator phase noise. Both of these modes of interference relate directly to the *selectivity curve* of the receiver, which is a function of the frequency separation between the desired and interfering signals. And as we will show, in-band power limits address both of these interference modes.

A fundamental property of all radio receivers is the fact that it is much more difficult to reject interference from sources that are close in frequency to the desired signal than it is to reject interference from sources that are significantly separated in frequency. A number of factors contribute to this basic fact. First, the filters used in radio systems attenuate out-of-band signals at an increasing rate as one moves away from the passband. Filters that perfectly pass the desired band while perfectly rejecting all other frequencies simply do not exist. This is true for fundamental physical reasons that no technology can overcome. Thus, interfering signals appearing at small frequency offsets from the desired

receive channel will be less attenuated than those appearing at large frequency offsets. Second, the local oscillators used in radio receivers for converting the incoming signal to lower frequencies for further processing have phase noise and spurious components that make them spectrally impure. These spectral impurities combine with interfering signals in the first mixer stage of a receiver to produce in-band interference at the first intermediate frequency of the receiver. This process is commonly referred to as "reciprocal mixing", and it is a well-known and important mode of interference in all receiver systems. Because the spectral impurities are worse at small frequency offsets, receivers are generally much more susceptible to reciprocal mixing from sources of interference that appear at small frequency offsets.

These two effects – imperfect filters and reciprocal mixing – cause receivers of all types to be much more sensitive to interference from sources at small frequency separations than they are to those at large frequency separations. Because of this increased sensitivity at small frequency offsets, the hazards of front-end overload and receiver desensitization become much more pronounced as the frequency of the interfering source approaches that of the victimized receiver.

We emphasize that, in the above paragraphs, we are *not* speaking about out-of-band emissions from the interfering system. Rather, we are speaking of interference that occurs due to in-band emissions from such systems, either directly or by virtue of interaction with spectral impurities in the local oscillator of the victimized receiver. Due to these important effects, we conclude that interference to a public safety receiver can indeed become worse simply due to increased proximity in frequency.

To compensate for the otherwise increased hazard imposed by frequency proximity, it is important to restrict the operating power of systems in the guard bands compared to that of systems in the 30 MHz commercial bands. For this reason, FreeSpace has repeatedly urged the Commission to impose a power spectral density limit of 4mW / kHz on systems operating in the guard bands. For a 500kHz channel bandwidth and an antenna gain of 6dBi, this is equivalent to 8W EIRP, or approximately 5W ERP. FreeSpace believes that

there are numerous valuable low-power commercial services that could be operated within such a transmit power restriction, which is roughly a factor of 200 less than in the 30 MHz commercial bands. Such a restriction on transmit power would provide strong, effective protection for public safety against interference from guard band systems while maintaining the commercial viability of the guard bands.

Out-of-Band Emissions Limits

A welcome side-effect of reducing the transmit powers permissible in the Guard Bands over those permissible in the Commercial Bands is that it becomes feasible to meet comparatively more stringent out-of-band emissions limits. In this section we consider what are the proper out-of-band emissions limits for guard band systems operating under the proposed transmit power restrictions, and how difficult those limits will be to achieve in practice.

FreeSpace has previously submitted a detailed technical analysis that justifies its proposed OOBE limit of 87 + 10log(P) for fixed transmitters operating in the second and third guard bands.[1] This analysis is based on a worst-case deployment of nodes and conservative assumptions about propagation conditions. Qualitatively, it should come as no surprise that a detailed analysis of OOBE limits for low-power services results in a somewhat more stringent limit than that for high-power services. Low-power systems will have smaller range, thereby permitting more sites within a given area than would be permitted with high-power systems. This promotes more efficient use of the spectrum, but without an adjustment in OOBE limits, would also present more opportunities for interference. To ensure that the interference radius also shrinks with the reduced transmit power, it is necessary to lower the OOBE limits to provide effective interference protection for public safety systems.

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[1] Letter of Charles Logan to Magalie Roman Salas, WT Docket No. 99-168 (filed Dec. 16, 1999). This technical analysis is also attached to this filing as Appendix B.

The most important goal in establishing strict OOBE limits for fixed transmitters in the guard bands is the protection of public safety mobile units receiving on 764 – 776 MHz. The adoption of reduced transmit powers in the guard bands raises an opportunity to further reduce OOBE emissions without imposing an unreasonable burden on manufacturers.

Indeed, there are existing systems that would meet this limit with only minor modifications when operating at 5W transmit power. For example, the GSM specification for European digital cellular phones calls for 60dB of attenuation at 400kHz offset from the center of the transmit band, based on fixed-bandwidth measurements made with a resolution bandwidth that is significantly less than the nominal transmitter bandwidth. Because the GSM channel bandwidth is 200kHz, a 400kHz offset corresponds to the center of the second adjacent channel. In comparison, under the proposed rules, a system with a 4mW / kHz (-24 dBm/Hz) transmit power spectral density would put out 14dBm in a 6.25kHz bandwidth (-24dBm/Hz + 10log(6250) = 14dBm). The proposed limit of 87 + 10log(P) would require that OOBEs fall below –57dBm, as measured in the same 6.25kHz bandwidth. Thus, the required attenuation is 71dB (14dBm – (-57dBm) = 71dB), which is only 11dB different than what is required under the GSM specification

The remaining gap of 11dB in this example could easily be closed for systems operating in the guard bands under the proposed power limits. Second adjacent channel emissions typically arise due to one of two possible sources: transmitter broadband noise, or fifth-order intermodulation distortion in the power amplifier. A reduction in broadband transmitter noise simply requires increased power consumption in the transmitter. Given that the proposed limit at issue here applies to fixed transmitters that presumably would have access to line power, an increase in the power consumption is not a significant problem. And, with current technology, it is certainly reasonable to achieve the 71dB of signal-to-noise ratio required to reduce broadband noise emissions to an acceptable level. The second possible source of the offending emissions is typically fifth-order intermodulation distortion in the power amplifier. Distortion products arising due to

fifth-order distortion mechanisms decrease very rapidly as the power amplifier's peak power rating is increased. In fact, these products fall off by approximately 50dB for every 10dB increase in the peak power rating, which is a ratio of 5:1 in dB. Thus, reducing these distortion products by 11dB would simply require that the power amplifier be designed for a peak output power of 2.2dB more than currently required to meet the GSM specification. This modest increase would not cause an unreasonable burden to manufacturers of guard band units under the proposed power limits because power amplifiers with peak power ratings far in excess of 5W are commonly available. The principal cost of the increased peak power is an increase in power consumption for the radio, but this is not a significant issue for fixed transmitters that have access to line power.

We conclude that the proposed guard band OOBE limit could be met with only modest modifications to existing GSM technology. Of course, this does not mean that GSM is the only technology suitable for deployment in the guard bands. But, this example establishes the important fact that the proposed emissions limits are not unreasonable for guard band operations, given current state of technology and the proposed power limits. In summary, the proposed guard band OOBE rule is reasonable, assuming that the transmit power is limited to 5W ERP, as proposed.

Adjacent Channel Emissions and Back-Off from the Band Edge

The adoption of strict OOBE limits has another important side-effect that directly addresses concerns raised by APCO about adjacent-channel emissions. In a recent letter to the Commission, APCO recommended that commercial guard band licensees be required, "upon notification that a public safety entity has received a license to operate on channels at or near the public safety 'band edge,' [to] ... reconfigure the frequency use at all of its base stations and associated mobiles within that public safety entity's service area to prevent adjacent channel interference." (Letter of Robert Gurss, Counsel for APCO, to Magalie Roman Salas, WT Docket No. 99-168 (filed Jan. 4, 2000).)

This recommendation is prompted by concerns about the potential for adjacent-channel interference. Spurious emissions in the first adjacent channels typically arise mostly due to unavoidable power amplifier distortion but are too close to the carrier to be suppressed by post power amplifier filtering. Third-order intermodulation distortion in real power amplifiers creates emissions in the channels immediately above and below the nominal transmit channel. These emissions will generally have a bandwidth that is roughly equal to the channel bandwidth, thus filling the adjacent channels with interference power. The resulting adjacent channel power level is typically between 30-50dB below the carrier power.

To address the problems introduced by first adjacent channel emissions, frequency coordinators generally pay specific attention not only to systems operating on the same channel (so-called "co-channel" systems), but also those that operate on each others' first adjacent channel. Thus, operations on the first-adjacent channel by guard band licensees are of particular concern to the public safety community. If a guard band system were to operate right at the edge of the Public Safety Band, its adjacent channel emissions would fall into the public safety band, thereby presenting an interference threat.

A direct solution to this problem is to craft a rule ensuring that adjacent channel emissions from guard band systems are always contained within the guard band. Thus, the guard band licensee should be required to, in effect, back off from the edge of the band to prevent adjacent channel interference. One approach is to write a rule explicitly stating that licensees should be required to back off. As an alternative, or as an additional safeguard, strict guard band OOBE limits can also accomplish this goal. An OOBE limit in excess of what can be achieved in the first adjacent channel will force guard band licensees to back off from the band edge by an appropriate amount.
We emphasize, however, that although the first adjacent channels present a special problem, it is still possible (as described above) to meet the 87 + 10log(P) limit *beyond* the first adjacent channel. Indeed, the previous section used a specific example involving second adjacent channel emissions, demonstrating that such emissions could easily meet the proposed limit. And, perhaps future advances in power amplifier technology will

make it possible to meet this limit in the first adjacent channel as well. Regardless, it is essential for the Commission to establish sufficiently stringent guard band OOBE limits to ensure protection from interference to public safety units. FreeSpace submits that its proposed guard band limit of 87 + 10log(P) achieves this goal by establishing a target that is strict, but reasonable.

B

Appendix B

A Technical Analysis of Necessary Adjacent Band Attenuation

There are a number of proposals before the Commission about the out-of-band spurious emissions limits necessary to provide adequate interference protection for public safety units that will operate in the 764 – 776MHz and 794 – 806MHz bands. FreeSpace Communications (FreeSpace) submits this technical filing to propose specific emissions limits that it believes, as set forth in the analysis below, will provide protection to public safety operations. FreeSpace is committed to ensuring that commercial services operating in guard bands adjacent to the public safety bands provide full protection against interference to public safety communications. We support the FCC's adoption of technical rules, including strong limits on out-of-band emissions, that are necessary to accomplish this objective. As a licensee of these guard bands, FreeSpace would of course comply with any rules the FCC requires to protect public safety.

The analysis set forth below shows that attenuating adjacent band emissions, as measured in a 6.25kHz bandwidth, by 84+10logP dB below the full-bandwidth transmitter power would be sufficient to protect public safety units from interference. This would result in an interference power at the input of the transmit antenna of no more than -54dBm in a 6.25kHz bandwidth. This is within 3dB of the -57dBm limit proposed by other parties in this proceeding. (*See* Letter of Leigh Chinitz, Motorola, Inc., to Magalie Roman Salas, WT Docket No. 99-168 (filed Dec. 2, 1999).) FreeSpace supports the adoption of this proposal, or, equivalently, a requirement that a guard band licensee attenuate its out-of-band emissions by a factor of not less than 87+10 log (P) in a 6.25 kHz bandwidth.

For our analysis, FreeSpace assumes the following conservative requirements to protect public safety mobiles and bases:

- Interference introduced into the public safety band should be at least 6dB below the noise floor of a typical public safety receiver.
- A typical public safety receiver has a noise figure of 8dB.
- There should be a very high confidence level that there be no interference to public safety receivers.

To meet the established emission limits in public safety spectrum, manufacturers should be required to demonstrate a specified attenuation of adjacent band spurious emissions (adjacent band attenuation, or *ABA*) at the interface to public safety spectrum. In adopting an approach for evaluating the necessary *ABA*, it is important to consider a method that is robust for the real-world propagation of radio-frequency signals. Therefore, this paper presents an analytical framework that is physically reasonable and as accurate as the uncertain radio environment will permit. In particular, FreeSpace adopts the following criteria:

- The analytical framework should be *physically reasonable* and as accurate as possible, given the unavoidable uncertainty of the radio environment.

- A primary concern is the probability that a fixed or mobile unit will experience interference under the adopted rules. Thus, the analytical framework should permit the specification of a *high confidence level that no interference will occur.*
- Radio propagation is difficult to predict due to the presence of multipath, ground reflections and attenuation by buildings, trees, etc. Thus, the analytical framework should support the specification of *margins* to guard against variations in propagation conditions. Furthermore, the framework should accommodate the use of the propagation model that leads to the adoption of *conservative requirements.*

In the following section, FreeSpace outlines a framework that meets the above goals and provides clear guidance on the selection of an appropriate *ABA* specification. A detailed discussion and mathematical derivation of the resulting formula for *ABA* is provided in the Appendix.

A Methodology for Determining Adjacent Band Attenuation Requirements

The transmit power and adjacent band attenuation of a transmitter are two factors that determine the radius at which a victimized mobile receiver from a neighboring system will experience interference. The transmit power also determines the coverage area of a cell, and thus the number of cells that are deployed. So, each cell produces its own interference region, and the probability that a victim mobile will wander into one of these regions is given by the ratio of the total area of all interference regions to the coverage area of the cellular system.

It is important to note that a potential victim becomes less susceptible to interference as it moves closer to its own base station. However, without knowing the relative positions of the base stations in the two systems, it is difficult to account for this effect. Thus, *a conservative analysis assumes that, regardless of position, the victim mobile must be able to operate at maximum sensitivity.* This simplification makes it possible to define a radius of interference that is the same for all cells, regardless of how close that cell is to the victim mobile's base station.

In particular, the area of the interference region is related to the following quantities:

- P_T – the transmit power of the interfering transmitter.
- ABA – the adjacent band attenuation of the interfering transmitter.
- G_T – the antenna gain of the interfering transmitter.
- G_V – the antenna gain of the victimized receiver.
- F_V – the noise figure of the victimized receiver.
- M_I – the interference margin, which determines the probability of interference at the boundary of the interference region.

Similarly, the coverage area of the interfering system is related to these quantities:

- P_T – the transmit power of the interfering transmitter.
- G_T – the antenna gain of the interfering transmitter.
- G_R – the antenna gain of the related receiver.
- F_R – the noise figure of the related receiver.
- $SNR_{\min}$ – the minimum signal-to-noise ratio for the related receiver.
- M_R – the receiver margin, which determines the probability of reception at the boundary of the cell.
- η – the degree of cell overlap.

It is straightforward to develop expressions for both the coverage and interference areas. The ratio of the areas then provides a *conservative* estimate of the probability of interference, or alternatively the confidence level that no interference will occur. The estimate is conservative because the victimized mobile receiver is assumed to be in a state of maximum sensitivity to interference, regardless of its position. In reality, this is not the case. Qualitatively, one can think of the confidence level as being *the probability that no interference will occur for victim mobiles operating near the boundary of their own coverage region.* Obviously, the further inside its own coverage area a victim receiver is, the greater the confidence level that no interference will occur.

Pursuing this approach, one can then solve for the required adjacent band attenuation in terms of the engineering quantities noted above. The resulting expression for adjacent band attenuation is

$$ABA = M_I M_R SNR_{\min} \frac{F_R}{F_V} \frac{G_V}{G_R} \left[\frac{\eta}{1 - CL} \right]^{N/2},$$

where M_I is the interference margin, M_R is the reception margin, $SNR_{\min}$ is the minimum signal-to-noise ratio required for reception in the interfering system, F_R is the receiver noise figure, F_V is the noise figure of the victimized receiver, G_V is the antenna gain of the victimized receiver, G_R is the antenna gain of the interfering system's receiver, η is the cell overlap factor, CL is the confidence level described above, and N is the propagation distance exponent (typically, $2 < N < 4$, with 2 corresponding to free space propagation conditions). Equivalently, when all quantities are expressed in dB,

$$ABA = M_R + M_I + SNR_{\min} + F_R - F_V + G_V - G_R + 5N\left[\log_{10} \eta - \log_{10}(1 - CL)\right].$$

A detailed derivation of this expression appears in the Appendix and follows the general approach outlined above.

Calculating the Required Adjacent Band Attenuation

To calculate the required adjacent band attenuation, we assume the following parameters:

Parameter	Value
M_R	13dB
M_I	19dB
$SNR_{\min}$	13dB
F_R	5dB
F_V	8dB
G_V	1.7dB
G_R	1.7dB
N	2, 4
η	2
CL	90%

The choice of parameter values can be explained as follows. The reception margin, M_R, is chosen with regard to *field propagation measurements* in suburban environments where the received signal power is described by a log-normal random process with about 10dB standard deviation. With this assumption, a receive margin of 13dB would place the cell boundary at a distance where reception occurs with 90% probability. Similarly, an interference margin, M_I, of 19dB places the interference boundary at a distance where the interference power is less than 6dB below the noise floor of the public safety receiver with 90% probability (6dB + 13dB = 19dB). The values for $SNR_{\min}$, F_R and F_V typify what can be achieved in practice without extreme effort. The values for G_V and G_R correspond to the antenna gains of short dipole antennas ($\lambda/10$). The overlap factor, η, assumes a large amount of overlap between cells.

Finally, the confidence level that no interference will occur, CL, is set to 90%. This level is consistent with propagation loss curves used by Motorola in its own interference analysis as described in a report that was presented to the National Coordination Committee.[1] Motorola's curves are based on field measurements of propagation loss. Based on these measurements, they claim a typical site isolation of 75dB, which is obtained with 90% confidence. In a similar fashion, the present analysis assumes a 90%

[1] In particular, this information was contained in the draft FLEWUG report presented to the NCC on November 19, 1999.

confidence level that the calculated adjacent band attenuation will provide the specified protection in the field. In addition, it is important to note that, in our methodology, the boundary of an "interference zone" is defined as *the radius at which a public safety receiver experiences an interference power exceeding 6dB below the receiver noise floor with only 10% probability*. Thus, a public safety receiver that finds itself in an interference zone will not *necessarily* experience real interference; rather, it will have a modest *probability* of receiving interference, and only if it is operating near the boundary of its own coverage area. Thus, as befits a *conservative* analysis, this cascade of probabilities implies that the real interference probability is significantly less than a simple reading of the numbers would indicate.

With the above assumptions, it is possible to compare the cases where $N = 2$ and $N = 4$ to see which propagation assumptions result in the more conservative specification for adjacent band attenuation. The result is summarized below:

	$N = 2$	$N = 4$
Required ABA	55dB	68dB

Significantly, the assumption that $N = 4$ is seen to be *conservative* with respect to determining the appropriate *ABA* requirement. As described in the Appendix, this result is physically reasonable because the greater acceleration in signal loss associated with fourth-law attenuation results in smaller cells for a given interference area, thereby implying an increased ABA requirement to achieve the same level of protection. In addition, this assumption, when combined with the use of margins to accommodate variations in the propagation environment, is a much more physical model that matches field measurements very well.

Note also that the expression for sideband attenuation does not include transmit power explicitly. This is due to the fact that the analysis assumes that cell sites are assigned to provide complete coverage at a particular transmit power. Thus, with this assumption, a decrease in transmit power implies a greater number of cells, with each cell having reduced interference and coverage areas. As a result, the *ratio* of interference and coverage areas does not change. It is this ratio, in part, that determines the confidence level that no interference will occur. Thus, although transmit power influences the distribution of the interference zones, it does not directly affect the overall confidence level.

For regulatory purposes, the expression for sideband attenuation given above corresponds to the transmit power spectral density by which cell sites are chosen. In the context of the FreeSpace proposal, this is the maximum power spectral density that can be used in the guard band, or 4mW/kHz (-24dBm/Hz). With 68dB of attenuation, the interference power produced at the input to the transmitter antenna in a 6.25kHz bandwidth would be –54dBm (-24dBm/Hz –68dB+10log(6250Hz) = -54dBm). We note that this power level is only 3dB less stringent than the level of –57dBm in a 6.25kHz bandwidth proposed by Motorola.

Of course, it is common sense that the required attenuation should be a function of transmit power. This guarantees that units operating at higher powers must meet more stringent requirements than those operating at lower powers. For this reason, we propose that the Commission adopt the following attenuation requirement for out-of-band emissions in a 6.25kHz bandwidth from units operating in the guard bands adjacent to public safety bands:

$$84 + 10\log_{10}(P_T),$$

where P_T is the transmit power into the transmitter antenna in watts. For absolute clarity, this equation should be interpreted to say that the out-of-band emissions power should fall below the transmit power by the stated attenuation, with the transmit power evaluated over the full bandwidth (e.g. the –26dB bandwidth) of the transmitter, and the out-of-band emissions power evaluated in a 6.25kHz bandwidth. Thus, a 1W unit operating under the FreeSpace proposal would have to produce no more than –54dBm interference power in a 6.25kHz bandwidth in the adjacent public safety band (30dBm – 84dB = -54dBm).

Although this rule may appear to be stringent, it is achievable within the context of a low power system and is thus consistent with the low power spectral density limits proposed by FreeSpace for use in the guard bands adjacent to public safety spectrum.

CONCLUSION

FreeSpace has outlined a method by which the appropriate adjacent band attenuation can be determined to protect neighboring public safety systems. The analysis is a conservative one that includes clear assumptions about what constitutes interference to a public safety receiver. Furthermore, the method presented includes margins based on field measurements to define coverage and interference boundaries that are conservatively defined to accommodate statistical variations in real-world propagation. FreeSpace's analysis shows that for guard band systems operating under the proposed power spectral density limits, an adjacent band attenuation of $84 + 10\log_{10}(P_T)$ in a 6.25kHz bandwidth is sufficient to confidently guarantee protection to public safety operations in the adjacent bands. This represents a *dramatic increase in attenuation* over the FCC's proposed rule of $43 + 10\log_{10}(P_T)$.

Although FreeSpace believes this level of attenuation will provide strong protection to public safety, it emphasizes that, as a licensee of the guard bands, it would of course comply with any technical rules, including out-of-band emissions limits, the FCC deems necessary to prevent interference to public safety systems.

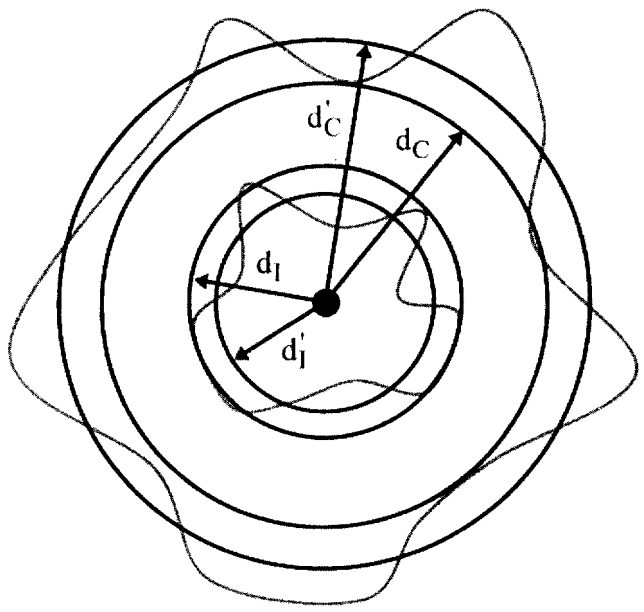

Figure 1. A typical cell. Not to scale.

Appendix: A Detailed Analysis of Adjacent Band Attenuation

Figure 1 illustrates a qualitative view of a typical radio cell. Although it is convenient to think of cells as having well-defined, circular boundaries, real cells have imprecise boundaries due to local variations in propagation conditions. These imprecise boundaries are illustrated as non-circular curves in the figure. Fortunately, these statistical variations are easily accommodated using margins in the analysis to determine a confidence level that a given boundary is contained within or without a specified radius. Suppose, for example, that the cell has an expected (i.e. average) radius give by d'_C and an expected interference radius of d'_I. With basic knowledge about the statistical distribution of received power, one can adopt margins that lead to the modified radii, d_C and d_I, which have a certain probability of respectively excluding or containing the real boundaries. For example, adopting an increased receiver margin results in a *reduction* in d_C because the reliability of reception improves as one moves towards the transmitter. In other words, for reliable reception it is important to be well *within* the average cell boundary. On the other hand, an increase in the interference margin results in an *increase* in d_I due to the fact that the probability of interference decreases as one moves away from the transmitter. In this case, to comfortably avoid interference, it is important to be well *outside* the average interference boundary.

With this understanding, it is possible to calculate the received power at radius d_C, and the interference power at radius d_I. By incorporating an adjacent band attenuation specification into the analysis, we can then relate these two quantities and develop a useful expression for the probability of interference.

A victim receiver at the boundary of the interference region accepts interference from adjacent band emissions of an interfering transmitter. The power spectral density of these emissions is attenuated below the transmit power spectral density of the interfering transmitter by the adjacent band attenuation, *ABA,* and the path loss from the transmitter, L_I. In addition, the bandwidth of the received interference power is determined by the effective noise bandwidth of the receiver, B_V. Thus, the received interference power is

$$P_I = \frac{(P_T / B_T) G_T G_V B_V}{L_I ABA},$$

where P_T is the transmitter power, B_T is the transmission bandwidth, G_T is the transmit antenna gain, G_V is the victim receiver antenna gain, B_V is the victim receiver bandwidth, L_I is the path loss to the victim receiver, and *ABA* is the adjacent band attenuation. The onset of interference occurs when the victim receives an interference power level that is below its own noise floor by a specified margin, M_I. Under this condition, the interference power is

$$P_I = \frac{F_V kTB_V}{M_I},$$

where F_V is the noise figure of the victim receiver, k is Boltzman's constant ($1.38*10^{-23}$), T is 290K, and M_I is the interference margin. Equating these two expressions and solving for L_I, yields an expression for the required path loss between transmitter and the victim receiver,

$$L_I = \frac{P_T G_T G_V M_I}{B_T ABA \cdot F_V kT}.$$

It is possible to perform a similar calculation at the cell boundary. At this distance, a receiver associated with the interfering transmitter receives a signal power, P_R, given by the path loss expression

$$P_R = \frac{P_T G_T G_R}{L_I L_{IC}},$$

where G_R is the receiver antenna gain, and L_{IC} is the additional path loss from the interference boundary to the cell boundary. Thus, the product $L_I L_{IC}$ is the *total* path loss from the transmitter to the cell boundary. For marginal reception, the received power must be above the receiver noise floor by the minimum acceptable signal-to-noise ratio, $SNR_{\min}$, times the required receiver margin, M_R. The received power at the cell boundary can thus be expressed as

$$P_R = M_R SNR_{\min} F_R kTB_R,$$

where F_R is the receiver noise figure, and B_R is the receiver bandwidth, which equals B_T. Equating these last two expressions, we can solve for the additional path loss from the interference boundary to the cell boundary, which yields

$$L_{IC} = \frac{P_T G_T G_R}{L_I M_R SNR_{\min} F_R kTB_R}.$$

Then, substituting the expression for L_I from above and canceling all of the common terms, results in a simple expression for the additional path loss,

$$L_{IC} = \frac{ABA}{M_I M_R SNR_{\min}} \frac{F_V}{F_R} \frac{G_R}{G_V}.$$

The additional path loss from the interference boundary to the cell boundary is directly related to the ratio of the distances from the transmitter to each boundary, and thus is also related to the areas of the cell and interference region. In particular,

$$L_{IC} = \left(\frac{d_C}{d_I}\right)^N = \left(\frac{A_C}{A_I}\right)^{N/2},$$

where A_C and A_I are the areas of the cell and interference region, respectively. Equating this expression with the previous one for L_{IC} leads to the following result

$$\left(\frac{A_C}{A_I}\right)^{N/2} = \frac{ABA}{M_I M_R SNR_{\min}} \frac{F_V}{F_R} \frac{G_R}{G_V}.$$

Note that this expression relates the ratio of the cell and interference areas to the required adjacent band attenuation in terms of relevant design quantities.

To determine the probability of interference based on this expression, it is necessary to extend it to accommodate multiple, overlapping cells. For this purpose, it is assumed that cells overlap with one another, but that the interference regions associated with the cells do *not* overlap. This is a *conservative* assumption that results in an increased probability of interference over what a single cell would provide. The degree of overlap is determined by an overlap factor, η, which is assumed to be greater than one. With overlap, each cell contributes an interference area A_I and a coverage area of A_C / η. The probability of interference is simply the ratio of these two. Thus, using the previous expression,

$$P(I) = 1 - CL = \frac{A_I}{(A_C / \eta)} = \eta \left[\frac{M_I M_R SNR_{\min}}{ABA} \frac{F_R}{F_V} \frac{G_V}{G_R}\right]^{2/N}.$$

This expression also introduces the parameter CL, which is the *confidence level that no interference will occur*. Finally, we can solve this expression for the required adjacent band attenuation, ABA, in terms of this confidence level, which yields

$$ABA = M_I M_R SNR_{\min} \frac{F_R}{F_V} \frac{G_V}{G_R} \left[\frac{\eta}{1 - CL} \right]^{N/2}.$$

This equation expresses the required adjacent band attenuation in terms of specified margins, cell overlap, and the confidence level that no interference will occur, given assumptions about propagation, the minimum signal-to-noise ratio of the receivers in the interfering system and the receiver noise figures and antenna gains of both systems. It is comforting to note that, qualitatively, the required ABA increases as we increase the margins, increase the desired confidence level that no interference will occur, and increase the number of cells (i.e. increase η). When all quantities are expressed in dB, we have

$$ABA = M_R + M_I + SNR_{\min} + F_R - F_V + G_V - G_R + 5N\left[\log_{10} \eta - \log_{10}(1 - CL)\right].$$

It is interesting to note that a larger N results in a more *stringent* SBA requirement, assuming that η is greater than unity and CL is positive and less than unity. Thus, it is *conservative* with respect to interference probabilities to assume fourth-law path loss conditions, where $N = 4$, over square-law path loss conditions, where $N = 2$. This is simply due to the fact that the increased attenuation rate associated with larger N implies that more cells will be required to cover a given area for a given radius of interference, thereby affording more opportunities for potential interference.