Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Amendment of Part 2 of the Commission's Rules to Allocate Spectrum Below 3 GHz for Mobile and Fixed Services to Support the Introduction of New Advanced Wireless Systems, including Third Generation Wireless Systems	)	ET Docket No. 00-258
	)	
Petition for Rulemaking of the Cellular Telecommunications Industry Association Concerning Implementation of WRC-2000: Review of Spectrum and Regulatory Requirements for IMT-2000	)	RM-9920
	)	
Amendment of the U.S. Table of Frequency Allocations to Designate the 2500-2520/2670-2690 MHz Frequency Bands for the Mobile-Satellite Service	)	RM-9911

JOINT COMMENTS OF THE
CELLULAR TELECOMMUNICATIONS & INTERNET ASSOCIATION
TELECOMMUNICATIONS INDUSTRY ASSOCIATION
PERSONAL COMMUNICATIONS INDUSTRY ASSOCIATION

The Cellular Telecommunications & Internet Association, the Telecommunications Industry Association, and the Personal Communications Industry Association hereby submit a report of the Industry Association Group (Association Group) on identification of spectrum for third generation wireless services (“3G services”). The purpose of the Association Group is to facilitate discussion of issues related to the accommodation of 3G services and to develop recommendations in as efficient a manner as possible. The proposals contained herein should form the basis of solutions for making a significant amount of suitable spectrum available for 3G services in a timely manner.

Wireless communications represents the most dynamic growth market in the telecommunications industry. Wireless subscribership is growing at an annual rate of 25 to 30 percent. In the United States, between June 1999 and June 2000, subscribership increased 27.2 percent to over 97 million.[1] This success has occurred on "first" generation analog, and "second" generation digital networks. The world stage is now set for continuing this growth with the "third" generation of services (3G services), which will provide a new range of services, including multimedia, video-conferencing, high speed Internet, speech and high-rate data. Around the world, countries in Europe and Asia have licensed or are in the process of licensing additional spectrum for 3G services. Such additional spectrum is critical to fostering the continued growth of mobile services and to enable hundreds of millions of people to enjoy the benefits of the wireless Internet.

The Council of Economic Advisors ("CEA") recognizes that 3G services offer tremendous benefits to consumers and the economy through the marriage of mobile and the Internet.[2] In its report, the CEA acknowledges the importance of making sufficient spectrum available to provide the full benefits of 3G services. The United States currently lags behind much of the developed world in the amount of spectrum available for commercial mobile services. This critical lack of spectrum places the United States at a competitive and economic disadvantage compared with other developed nations. Moreover, the lack of spectrum threatens to put the United States further behind the in development and deployment of wireless Internet services. The United States, however, has undertaken the important task of identifying additional spectrum for deployment of

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[1] The World of Wireless Communications, Statistics and Surveys, CTIA's Semi-Annual Wireless Industry Survey available at http://www.wow-com.com.

3G services, by initiating a process to review the use of frequency bands identified by the ITU as potential 3G bands. It is imperative that the United States follow through on this effort and ensure its success in identifying and making available a significant amount of spectrum suitable for 3G services.

By letter dated November 10, 2000, to the Chairman, Federal Communications Commission and the Assistant Secretary of Commerce Administrator, NTIA, the Association Group provided the following underlying principles that should guide the identification of spectrum for 3G services:

1. Sufficient spectrum must be made available for 3G. ITU-R Task Group 8/1 (TG 8/1) estimated that an additional 160 MHz of spectrum will be required to support 3G services through 2010. This amount is in addition to the spectrum already used for 1st and 2nd generation mobile services and in addition to spectrum identified for 3G at the 1992 World Administrative Radiocommunication Conference (WARC-92).[3]

2. Spectrum should be harmonized globally, to the greatest extent possible. The availability of spectrum in the United States that is harmonized with spectrum allocations around the world will promote global roaming for U.S. consumers and improved interoperability between U.S. networks and networks operating in other countries. It will improve economies of scale for manufacturers and service providers, and thus, decrease the cost of equipment and services provided to consumers. It will provide consumers with greater access to new voice, data and multimedia services that are offered worldwide. And, it will improve the competitive position of U.S. wireless companies in the global marketplace. The agreement reached at WRC-2000 supports the harmonization of 3G spectrum, and identifies specific bands for 3G development. Appropriately, the U.S. Government's plan focuses on the two bands that were identified at WRC-2000, specifically 1710-1885 MHz and 2500-2690 MHz.

3. Spectrum should be made available in time to meet market needs. Countries in Europe and Asia are already licensing spectrum for 3G in accordance with actions taken at WARC-92. For these countries, the additional spectrum identified at

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[2] *The Economic Impact of Third-Generation Wireless Technology*, A Report by The Council of Economic Advisors, October 2000.

[3] See *Recommendation ITU-R M.1390, Methodology for the Calculation of IMT-2000 Terrestrial Spectrum Requirements* and *Recommendation ITU-R M.2023, Spectrum Requirements for International Mobile Telecommunications-2000 (IMT-2000).*

WRC-2000 is intended to satisfy market demand that is expected to develop by 2010. In the United States, however, the spectrum identified at WARC-92 is already being used for 2nd generation mobile services (PCS). Substantial portions of additional spectrum must be available in the near term to accommodate the development of 3G.

4. Evolution to 3G in existing spectrum does not mitigate the need for additional 3G spectrum. Wireless service providers that operate 1st and 2nd generation mobile systems should be permitted to evolve their systems to 3G within their current bands. We acknowledge the U.S. Government's past support for such evolution and encourage it to continue to support technology neutral policies. Many U.S. operators are already making plans to begin deploying 3G technologies in their existing spectrum. However, that spectrum is not sufficient to meet the expected demand for the full range of 3G services. It is important to note that the work performed by TG 8/1, which concluded that 160 MHz of additional spectrum would be needed for 3G, assumed that evolution within existing allocations would occur.

5. Access to 3G spectrum must be unencumbered. Simply auctioning spectrum is not enough. Operators must be able to use the spectrum without receiving harmful interference. Consequently, adequate sharing rules must be established or incumbent users must be cleared from the band. These issues will need to be resolved quickly if the United States is to avoid falling behind Europe and Asia in its 3G development.

6. Spectrum must accommodate 3G services. The deployment of 3G technologies requires relatively large, contiguous blocks of spectrum. In completing its spectrum studies and developing potential band segmentations, the U.S. Government should ensure that the spectrum made available for 3G will accommodate the 3G technologies that are currently available or planned while minimizing the cost and complexity of such systems.

7. Technological advances will not solve spectrum scarcity. The wireless industry continues to actively research and develop advances in technology that will promote greater spectral efficiency. We encourage the U.S. Government to establish policies that facilitate the use of various technologies, including Software Defined Radios or adaptive antennae that will assist the industry in this area. However, such technologies will not alleviate the need for additional spectrum in the short to medium term. While the successful development of such technologies would undoubtedly have an effect on spectrum use over the longer term (i.e. beyond 2010), reasonable assumptions about near term technological advances were taken into account in the work performed by TG 8/1. Any difference in spectral efficiency among the 3G standards approved by the ITU in May 2000 would not reduce the need for additional spectrum as indicated above.

The current process has primarily focused on evaluating the 1710-1850 MHz and the 2500-2690 MHz bands, which were identified at WRC-2000 as potential 3G frequency bands.[4] Under the current process, the NTIA and the FCC released interim reports providing information on current uses of the 1710-1850 MHz and 2500-2690 MHz bands respectively, including an initial analysis regarding accommodation of IMT-2000.[5] Recognizing the need for detailed analysis of the incumbent systems in these bands, the Association Group, developed a work program intended to assist Government efforts to identify spectrum for 3G services.[6] Specifically, the work program is structured based on the incumbent systems that require study and addressed in the NTIA's and FCC's interim reports. Under this program, a series of four meetings were held over a two-month period. These meetings provided an appropriate venue for the detailed discussions necessary to better understand the incumbent operations, and to explore ways to meet the continuing communications requirements of the incumbents, while also making spectrum available to meet the rapidly increasing requirements for commercial mobile services.

As a result of this effort, the Association Group provides the Commission with the attached report which includes solutions that satisfy the communications requirements of all of the interested parties, including both incumbents and 3G proponents. While the Association Group anticipates that further discussions to continue defining the operational and technical details of its proposed solutions, these proposals support making spectrum available for 3G services in the United States.

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[4] *Additional Frequency Bands Identified for IMT-2000*, WRC-2000, Resolution 223.

[5] *Federal Operations in the 1755-1850 MHz Band: The Potential for Accommodating Third Generation Services*, *Interim* Report, U.S. Department of Commerce, National Telecommunications and Information Administration, November 15, 2000; *Spectrum Study of the 2500-2690 MHz band, Interim Report*, Federal Communications Commission, November 15, 2000.

[6] Letter from Michael Altshul, CTIA, Robert Hoggarth, PCIA, and Grant Seiffert, TIA to the Honorable William K. Kennard, Chariman, FCC, Federal Communications Commission and The Honorable Gregory L. Rohde, Assistant Secretary of Commerce, Administrator, NTIA, Dec. 8, 2000.

The Association Group looks forward to working with the NTIA, the FCC, the U.S. Department of Defense, and other interested parties to help bring the benefits of 3G services to the American people.

Respectfully submitted,

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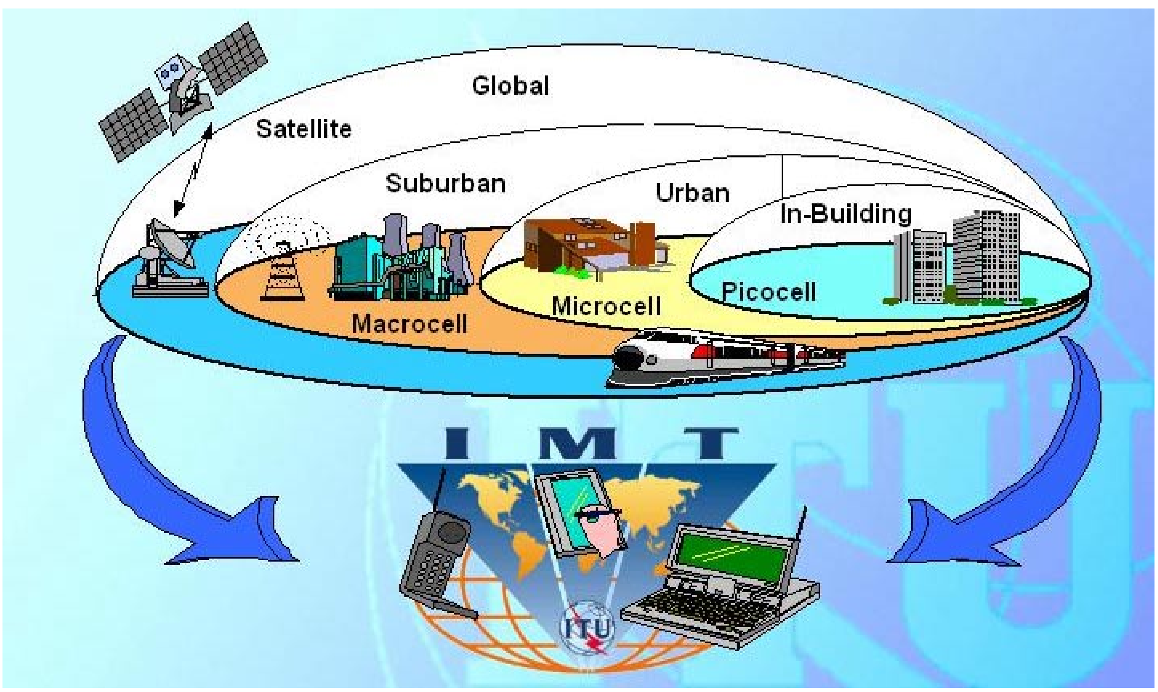
February 22, 2001

Report of the Industry Association Group on Identification of Spectrum For 3G Services



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EXECUTIVE SUMMARY

The Cellular Telecommunications & Internet Association (CTIA), the Telecommunications Industry Association (TIA), and the Personal Communications Industry Association (PCIA) collectively represent a majority of the wireless industry interested in developing and deploying 3G communications services. A critical component of deploying such service in the United States is obtaining additional spectrum for commercial mobile services. To facilitate the discussion of issues related to the accommodation of 3G services in frequency bands under consideration and develop recommendations in as efficient a manner as possible, these associations established the 3G Industry Association Group (Association Group). The proposals contained herein form the basis of solutions for making a significant amount to spectrum available for 3G services in a timely manner.

Over a two month period beginning mid-December 2000, the Association Group held a series of meetings to review the information provided in the interim reports of the NTIA and the FCC,[7] in order to develop viable proposals for accommodating 3G systems in the 1710-1850 MHz and 2500-2690 MHz bands while also satisfying communications requirements of the incumbent operations. The industry invited the NTIA, the FCC and the U.S. Department of Defense (DoD) to participate in these meetings in order to provide more meaningful dialogue and understanding of each other's requirements and objectives, and as a way to support the Industry Outreach Program initiated by the U.S. Department of Commerce. There was significant and meaningful participation by all interests in the meetings, and this exchange has provided the basis for proposed solutions to making spectrum available for 3G services while meeting the needs of incumbents. This report, however, is an industry report and participation in the industry discussions by the FCC, NTIA, and DoD does not imply that these parties have agreed to these recommendations.

The focus of the Association Group meetings was to develop technical and operational proposals either for sharing between 3G and incumbent systems or for relocation of incumbent systems. The effort did not focus on specific band plans or band segmentation options, but rather on whether solutions could be found that would make an entire band available, or whether the needs of a system could be met in a relatively small portion of a band. Based on this analysis, it appears that all or most of the 1710-1850 MHz band can be made available for 3G services through a combination of geographic or time sharing with some of the incumbent services and relocation of incumbents when sharing is not feasible. While there was considerable discussion of options for use of the 2500-2690 MHz band, much of the discussion centered on policy issues. The

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[7] *Federal Operations in the 1755-1850 MHz Band: The Potential for Accommodating Third Generation Services*, *Interim* Report, U.S. Department of Commerce, National Telecommunications and Information Administration, November 15, 2000 (NTIA interim report); *Spectrum Study of the 2500-2690 MHz band, Interim Report*, Federal Communications Commission, November 15, 2000 (FCC interim report).

Association Group agreed that such issues are more appropriately addressed in the FCC rule making proceeding. While there was no agreement on technical solutions for accommodating 3G services in the 2500-2690 MHz band, this report identifies areas of study.

3G Characteristics

The Association Group reviewed the 3G characteristics used in the FCC and NTIA interim reports and revised them to more accurately describe the technical characteristics of 3G systems and to include Time Division Duplex technologies. These refined characteristics accurately reflect information found in ITU-R Recommendation 1457 and supporting industry standards. It was agreed, however, that the refined characteristics are sufficiently similar to the characteristics used in the interim reports that it is not necessary to revise the preliminary interference studies included in the interim reports solely because of the revised characteristics.

1710-1850 MHz

The proposals presented in this report include the 1710-1755 MHz portion of the 1710-1850 MHz band. Although this portion is available for non-Government use on a shared basis with Government pursuant to the Omnibus Budget Reconciliation Act of 1993, the conditions imposed in NTIA's Final Relocation Report make the band unsuitable for commercial use for services such as 3G.[8] Accordingly, modifications to the sharing conditions must be made prior to consideration of the band for 3G.

The DoD and NTIA interim reports describe four major systems operating in the 1710-1850 MHz band, 1) Satellite Control Systems for tracking, telemetry and control of Federal space systems, 2) medium-capacity, conventional fixed microwave communications systems, 3) military tactical radio relay radios, 4) air combat training systems.[9] Proposals for sharing with or relocating Federal Government users in the 1710-1850 MHz band in order to make all or most of this band available for 3G are summarized below:

Satellite Control Systems

Analysis submitted in the Association Group indicates that interference from IMT-2000 into satellite receivers will be at acceptable levels and that sharing between IMT-2000 and satellite receivers is possible without any mitigation. Based on this analysis, existing satellites will be able to operate throughout their life span.

Interference from satellite control uplinks into IMT-2000 will cause unacceptable interference to IMT-2000. Earth stations located in or near urban and suburban areas, will have an unacceptable impact on the capacity of an IMT-2000 system. There are, however, only a limited number of Earth station facilities and it is feasible to relocate

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[8] *Spectrum Reallocation Final Report (Reallocation Final Report)*, U.S. Department of Commerce, February, 1995.

[9] NTIA Interim report at 13; *Investigation of the Technical Feasibility of Accommodating the International Mobile Telecommunications (IMT) 2000 Within the 1755-1850 MHz band, Interim report*, Department of Defense IMT-2000 Working Group, 27 October, 2000 (DoD interim report) at 1-1.

these to rural areas as a short-term solution. Relocation of earth stations will allow IMT-2000 to access this spectrum in the short term, while allowing the existing satellites to operate throughout their life span. The long-term solution is to migrate satellite operations to the 2025-2110 MHz band as new satellites replace existing systems. This will allow a 10-15 year migration that will not adversely impact DoD satellite operations. To limit adjacent channel interference to IMT-2000 in rural areas, baseband filtering must be added to the Earth stations and the stations should operate with the minimum power necessary to provide reliable communications with the satellites.

Conventional Fixed Point-to-Point Systems

Because of the wide-spread deployment of fixed point-to-point microwave systems, it is not feasible for a ubiquitously deployed mobile system like 3G to share with these systems on a time, geographic, or frequency basis. Fixed systems in this band are however, very similar to those used by the private sector, which were relocated to allow introduction of PCS in the 1.9 GHz band. It is feasible to relocate these systems to commercial systems, fiber optic, frequency bands above 3 GHz that are available for Government fixed point-to-point systems, or, possibly, non-government frequency bands available for point-to-point operations in cases where a link can not be accommodated by other means.

Tactical Radio Relay

Tactical Radio Relay systems are frequency agile and it is feasible to share with 3G on the basis of geographic and frequency segmentation. DoD capacity requirements should be heaviest in rural areas, where large scale training operations are conducted. IMT-2000 capacity requirements are greatest in urban areas and decrease in rural areas. It is therefore feasible to allow IMT-2000 to access all or most of the 1710-1850 MHz band in urban areas and to provide DoD access to increasing amounts of this band in increasingly rural areas. Frequency coordination will have to be well defined to ensure that each IMT-2000 operator will have access to a minimum amount of spectrum nationwide in order to ensure that customer requirements can be met.

Because tactical radio relay systems are frequency agile, they also have access to spectrum outside of the 1710-1850 MHz band. In areas immediately adjacent to urban areas, it's expected that spectrum requirements for training will be very low and it should be feasible for the systems to operate in Federal Government frequency bands outside of 1710-1850 MHz. To provide additional flexibility for operation of tactical radio relay systems, the FCC also should explore ways of allowing access to non-Government frequency bands in areas where non-Government licensees have excess capacity and are not using their licensed spectrum.

Air Combat Training Systems

Air Combat Training Systems (ACTS) operate from airborne platforms and have the potential to cause and receive interference over a large geographic area. It is, therefore, not feasible to share with ACTS on a geographic segmentation basis. It also does not appear feasible to segment the 1710-1850 MHz band in a way that will allow compatible operation of the current Air Force's Air Combat Maneuvering Instrumentation (ACMI) System or the identical Navy Tactical Aircrew Combat Training System (TACTS). Both the NTIA and DoD interim reports indicate that the existing systems are being replaced by a new Joint Tactical Combat Telemetry System (JTCTS).[10] It is feasible for JTCTS to operate in relatively narrow band segments over land and these operations can be accommodated in spectrum used as guardbands for IMT-2000. The migration to JTCTS should be expedited and the JTCTS receivers should be made more efficient by limiting the passband to be equal to the transmitter bandwidth.

While there is still considerable work that needs to be done to develop the technical and operational details of the above-described proposals, we believe that they provide the basis for a solution that will make a significant amount of spectrum available for 3G services while also meeting the continuing requirements of Federal Government users. Making the 1710-1850 MHz band available for 3G services satisfies all of the guiding principles set forth in the Association Group letter of Nov. 10, 2000.[11] For instance, when combined with other bands, such as the 2110-2150 MHz and 2160-2165 MHz bands, it provides sufficient spectrum to meet 3G requirements through at least 2010. The 1710-1850 MHz and 2110-2150 and 2160-2165 MHz bands are also used by most of the world for commercial mobile services, can be harmonized globally and can be made available in the U.S. in time to meet market demands. Using the above proposals for sharing and relocations as a basis, it is feasible to make the 1710-1850 MHz band available for use by 3G services in two to three years, in accordance with clearly defined operational rights.

2500-2690 MHz

There was considerable discussion in the Association Group's meetings regarding the use of the 2500-2690 MHz band to accommodate 3G services. The group addressed the potential for sharing the band among ITFS/MDS and 3G users, and concluded that co-channel sharing was not possible. The group also addressed the possible segmentation of the band to accommodate 3G, but could not reach agreement on the feasibility of this option. It did, however, make several recommendations for further FCC review. First, the Commission should investigate more fully the current and planned uses of the band for commercial and educational purposes by ITFS and MDS incumbents. Second, the Commission should determine whether alternate spectrum is available to accommodate the relocation of incumbent systems and what specific technical and economic impacts relocation would have on incumbents. Third, the Commission should determine whether more flexible service rules and secondary market mechanisms would facilitate the use of 2500-2690 MHz for 3G services.

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[10] DoD interim report at E-1. NTIA interim report at 25.

[11] Letter from Michael Altshul, CTIA, Robert Hoggarth, PCIA, and Grant Seiffert, TIA to the Honorable William K. Kennard, Chariman, FCC, Federal Communications Commission and The Honorable Gregory L. Rohde, Assistant Secretary of Commerce, Administrator, NTIA, November 10, 2000

BENEFITS TO FEDERAL GOVERNMENT USERS

This report demonstrates that potential solutions are available for accommodating 3G services in the 1710-1850 MHz band and that doing so meets the guiding principles provided by the Association Group in its November 10, 2000 letter to the NTIA and the FCC.[12] In addition to the consumer and economic benefits outlined in this report, reallocation of the 1710-1850 MHz has significant benefits for Federal Government users. Specifically, reallocation of 1710-1850 MHz provides an opportunity for DoD to modernize its communications systems and align its operations with the use of spectrum globally. Such reallocation provides long-term benefits to the military, particularly as the military transitions to a lighter mobility force that is heavily dependent on communications and often required to participate in smaller scale conflicts or in peace keeping missions around the world.

The 1710-1850 MHz band is used by most of the developed world for commercial mobile services. The DoD satellite operations in this band do not conform to the standard world-wide operations for similar satellite services. DoD conducts its telemetry, command and control operations using the 1761-1842 MHz band as an uplink paired with the 2200-2290 MHz band for downlink communications. The ITU standard pairing for this type of communications, on the other hand, is to use the 2025-2110 MHz band as the uplink paired with the 2200-2290 MHz band for the downlink. DoD has harmonized its operations in the downlink direction, but uses a non-standard uplink. Standardizing its operations in both the up and downlink directions will facilitate the long-term accommodation of its satellite operations and will help ensure that its uses will not be interfered with, or cause interference to the rapidly increasing commercial mobile operations that are deployed globally in the 1710-1850 MHz band.

Many of the Federal Government fixed point-to-point systems are analog and have been in use for many years. Relocation provides an opportunity to upgrade the quality and reliability of these systems to more efficient digital operations. As noted in the NTIA report, aging analog equipment operating in the 1710-1850 MHz band will eventually require replacement. However, due to the reallocation of services from the band, there is no digital equipment available to replace the existing systems in this band.[13] Some Federal users, such as the U.S. Coast Guard and the Department of Justice, have already begun to transition fixed operations into higher frequency bands.[14] Relocation as part of an effort to provide spectrum for IMT-2000 provides an opportunity for Federal users to be fully compensated for the cost of relocation and to upgrade systems to more reliable and spectrally efficient digital operations.

In the case of tactical radio relay systems, the NTIA and DoD interim reports indicate that current systems are being replaced by systems that operate over an even wider

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[12] Letter from Michael Altshul, CTIA, Robert Hoggarth, PCIA, and Grant Seiffert, TIA to the Honorable William K. Kennard, Chariman, FCC, Federal Communications Commission and The Honorable Gregory L. Rohde, Assistant Secretary of Commerce, Administrator, NTIA, November 10, 2000.

[13] NTIA interim report at 24.

[14] NTIA interim report at 23.

expanse of spectrum. While the solution proposed for accommodation of 3G involves shared use of the 1710-1850 MHz band rather than complete systems relocation, access to additional frequency bands will help in meeting the military communication requirements. Accordingly, this proposal provides an opportunity for the U.S. government to facilitate deployment of the new communications systems, to the extent that additional frequency bands are identified that could accommodate this use, compensation could be provided to further expand the frequencies and capabilities of the system. More efficient use of the U.S. spectrum resource also is possible through greater shared use of non-Government bands for Government operations. Thus, the U.S. Government should consider mechanisms that would allow these Government systems to use non-Government bands that they do not currently have access to in geographic areas where non-Government use of a frequency band is limited. Because DoD conducts training operations around the world, including areas where the 1710-1850 MHz band is used for commercial mobile operations, a movement away from this band as a primary band for these systems will allow DoD to operate in a manner more compatible with the global use of spectrum. This is also advantageous in limited combat or peacekeeping missions, where operations may interfere with or cause interference to friendly countries not involved in the conflict or supporting U.S. efforts.

Aligning Air Combat Training operations with global use of spectrum also will facilitate the global training requirements of military forces. As the DoD report concludes, airborne systems will cause and receive interference over large geographic areas. At a time when the United States is are working more closely with allies and forces are increasingly required to conduct training overseas, it is important that the spectrum used for training is compatible with global use. In making spectrum available for 3G services, the DoD has the opportunity to modernize its training communications equipment, providing greater flexibility in how the training is conducted, enabling more information to be transmitted during training, and facilitating overseas training through better spectrum alignment.

Providing spectrum for 3G services promises benefits that are not just limited to the telecommunications industry. The benefits will extend throughout the economy and will be enjoyed at nearly all levels of society. Further discussion between all parties will allow the technical and operational details of the proposals made herein to be more fully developed, in order to make the 1710-1850 MHz band available for 3G services.

INTRODUCTION AND BACKGROUND

On November 14, 2000, the NTIA and the FCC released interim reports considering the possibility of accommodating 3G operations in the 1710-1850 MHz and 2500-2690 MHz bands respectively. Recognizing the need to facilitate in-depth dialogue regarding the use of these bands and the potential for accommodating 3G services, CTIA, TIA, and PCIA established the Industry Association Group. Over a two month period beginning December 2000, the Association Group held several meetings and invited the NTIA, FCC and DoD to participate. These meetings provided an important forum for exchanging information and ideas regarding the accommodation of 3G services in the frequency bands under study and the systems currently operating in the bands. These meetings also served to provide input and support to the Government Industry Outreach Program mandated in the Presidential Memorandum of October 13, 2000.

This document provides a report of the industry meetings and activities, and provides recommendations for making spectrum available for 3G services. Although this work has been done in a very compressed time frame, the proposals presented forms the basis of solutions that make a significant amount of spectrum available for 3G services, satisfy the communications requirements of incumbents, and result in more efficient use of the scarce spectrum resource. There is, however, a significant amount of work remaining to fully develop the technical and operational details of these proposals. Moreover, while the NTIA, FCC, and DoD fully participated in the industry meetings, their participation does not indicate agreement with the recommendations of this report. Continued discussions between all parties are necessary to fully develop these proposals. Based on analysis to date, it appears that viable solutions exist that would allow use of most or all of the 1710-1850 MHz band for 3G services on a either a shared basis with Federal operations or through relocation of Federal operations. Because the 1710-1850 MHz band is used for commercial mobile services in much of the developed world, and is favored for use by a large number of countries that do not use it currently, it is particularly attractive for use in the United States as a harmonized global band for 3G services. Providing a workable solution for both Federal users and the private sector will benefit all parties in the long-term, by ensuring compatible operation with global requirements.

With respect to the 2500-2690 MHz band, the Association Group agreed that co-channel sharing is not a feasible option with 3G services. If 3G services are to be accommodated in this band, it would have to be done through relocation for ITFS and/or MDS, or through policy-based regulatory mechanisms. Additional discussion of these issues is contained in this report.

DETAILED OVERVIEW OF RECOMMENDATIONS

3G Characteristics

One of the first tasks undertaken by the Association Group was to a review of the 3G characteristics used for the sharing analysis included in the FCC and NTIA interim reports. The Association Group revised the characteristics to more accurately describe the technical characteristics of 3G systems and to include Time Division Duplex technologies. These refined characteristics accurately reflect information found in ITU-R Recommendation 1457 and supporting industry standards. It was agreed, however, the refined characteristics are sufficiently similar to the characteristics used in the interim reports that it is not necessary to revise the preliminary interference studies included in the interim reports solely because of the revised characteristics. Differences would only become apparent in the event that very detailed analysis is required. A revised characteristics table is included as part of this Association Group report.

The 1710-1850 MHz Band

The preliminary NTIA and DoD report addressing the use of the 1710-1850 MHz band identifies four major system classes operating in the band: 1) tracking, telemetry and control of Federal space systems, 2) medium-capacity, conventional fixed microwave communications systems, 3) military tactical radio relay radios, 4) air combat training systems.[15] This report addresses each of these systems.

Satellite Control Systems

The DoD conducts satellite operations (SATOPS) in the Earth-to-Space (uplink) direction in the 1761-1842 MHz portion of the 1710-1850 MHz band, with the Space-to-Earth (downlink) portion of the link being in the 2200-2290 MHz band. The DoD SATOPS track and control a wide variety of satellites at various orbital altitudes. These operations are conducted in accordance with footnote G42 of the Table of Frequency Allocations. They, however, do not follow the conventional ITU pairing for such operations that pairs the uplink band 2025-2110 MHz with the 2200-2290 MHz downlink. The majority of global SATOPS operations by other administrations and by NASA are conducted in accordance with the standard ITU pairing. Considering the current and rapidly increasing global use of the 1710-1850 MHz band for commercial mobile services, it would be beneficial for DoD to migrate its global satellite operations to correspond with the globally recognized SATOPS operations using 2025-2110 MHz for the uplink. Because DoD already uses the standard downlink, these systems would be unaffected. Given the existing use of the 2025-2110 MHz band, it is feasible for DoD to migrate its SATOPS use to this band over the longer term, as existing satellites are replaced.

Migrating to the 2025-2110 MHz band should be cost effective. Transmitters and receivers for the band are available, as the band is widely used for this purpose. Because

[15] NTIA Interim report at 13; DoD interim report at 1-1.

the band is relatively close to the 1710-1850 MHz band, the cost of equipment should be nearly identical to equipment currently employed by DoD. There also should be no technical reasons prohibiting such migration. Transmitters for the 2025-2110 MHz band would have to be added to SATOPS Earth stations. Existing satellites would continue to use the 1761-1842 MHz band through their lifespan, as described below, but new satellites would use the 2025-2110 MHz band.

In the case of short term accommodation of 3G services, the DoD and NTIA reports indicate that it is not possible to retune or change the channels used for SATOPS on existing satellites. Given that the operational life of some of the satellites is in excess of ten years, it is necessary for SATOPS to be performed in the 1761-1842 MHz band for an extended period. Any solution that makes spectrum available for 3G systems must either provide a mechanism for sharing with SATOPS operations or must include a phased implementation that would limit spectrum available for 3G services during the period it would take to replace the existing satellites.

Interference from IMT-2000 into satellite operations

Interference analyses, which are based on the 3G systems parameters set forth in ITU-R Recommendation 1457 and supporting industry standards as well as Federal satellite assets identified in the DoD and NTIA reports, demonstrate that interference from 3G systems into the satellite assets will be limited to acceptable levels, considering 3G build-out through the year 2015. Calculations using worst case analysis demonstrate that positive link margins will continue to exist through 2015 regardless of whether the analysis is done for interference from base stations or mobile stations.

Considering that the satellites see such a large percentage of the world, and the band is used globally for commercial mobile services, there is very little difference in the level of interference received by the satellites regardless whether the United Statees makes the band available for 3G services, particularly for satellites in higher orbits.[16] Sharing between IMT-2000 and SATOPS is therefore feasible with respect to interference into the satellites, with no mitigation necessary for the IMT-2000 systems.

Interference into IMT-2000 systems from Satellite control facilities

Analysis based on parameters for 3G systems found in ITU-R Recommendation 1457 and supporting industry standards and the SATOPS uplink facilities, indicates that interference from SATOPS earth stations will exceed acceptable levels into IMT-2000 operations when considering either the mobile or base station case. Although there are a limited number of uplink facilities, the locations of some of the facilities will create interference in dense urban areas where demand for mobile services is greatest. In addition, the current channelization of the SATOPS control channels, centered

[16] In evaluating sharing between mobile services and satellite operations, the effect of interference from other countries on the ability of DoD to communicate will vary depending on the orbital altitude of the satellite. Communication with satellites from Earth stations located in the United States is generally considered more critical than communications with the satellites from other locations. Furthermore, low Earth orbiting satellites will experience less interference from other countries when over the United States than satellites at higher orbits, such as Geostationary.

approximately every 4.004 MHz, makes it impossible to limit the interference to a single IMT-2000 channel at a time. Therefore, instances of interference have the potential to eliminate the majority of an operator's capacity in densely populated areas where maximum capacity is most critical.

There are, however, factors that can mitigate this interference and steps that can be taken to limit the interference to acceptable levels until such time as SATOPS can be relocated to another frequency band. SATOPS are performed from a very limited number (10-15) of locations in the United States.

Based on discussions during the Association Group meetings, the following factors are taken into consideration in developing a method for accommodating IMT-2000 in the band used for SATOPS:

1) It is not possible to limit the interference to IMT-2000 by limiting the operational elevation angles for earth stations

2) It is not possible to coordinate IMT-2000 and SATOPS operations on a time basis by limiting the times during which the earth stations use certain channels.

3) The SATOPS stations use minimum power necessary to close the link with the satellites. However, it is not acceptable to prevent the earth stations from operating at maximum power in the event that such operation is necessary to provide sufficient link margin. Thus, while worst case conditions (low elevation, maximum power) are not expected to be typical, they must be considered.

4) Shielding around the earth stations is not sufficient to eliminate unacceptable interference to IMT-2000.

5) It is feasible to install baseband filtering on the earth stations in order to significantly limit out-of-band emissions from SATOPS.

Considering the above assumptions, it is not possible for SATOPS to share with IMT-2000 in populated areas where 3G capacity requirements are greatest. However, considering the limited number of Earth station facilities, it should be possible to relocate facilities from densely populated areas to remote, sparsely populated areas. 3G capacity requirements will be considerably less in remote areas and temporary loss of capacity in such areas should be acceptable, particularly at the early stages of IMT-2000 deployment when subscriber loading is low and build-out is likely limited to more densely populated areas.

Accordingly, sharing between SATOPS and IMT-2000 appears feasible under the following conditions:

1) SATOPS Earth station facilities are relocated at least 100 km from cities of 50,000 or greater. Relocation is feasible in the short to medium term

(approximately 2-3 years). The cost of such relocation will have to be determined.

2) Baseband filtering is added to the earth station transmitters.

3) SATOPS are conducted using the minimum power necessary to close the link with the satellite with satisfactory link margin.

4) A coordination mechanism is implemented so that the IMT-2000 system can avoid using channels used by SATOPS in the area around and Earth station. One such coordination mechanism is the Earth station notifying the IMT-2000 operator prior to using a channel. The mechanism and timing for notification will need to be determined.

5) To facilitate sharing, SATOPS systems should select the channels, to the extent possible, that minimize interference to IMT-2000 systems. For example, if a satellite has the capability to communicate on multiple channels, the channel that has the least impact on IMT-2000 should be selected. Satellites that have not yet been launched should be either retuned to operate in the 2025-2110 MHz band or, if it is not feasible to retune these satellites for the 2025-2110 MHz band, should be retuned to operate on channels in the 1761-1842 MHz band that have the least potential for interference to IMT-2000 systems. The optimal channels will depend on the band plan ultimately adopted for IMT-2000.

Relocation of satellite operations to 2025-2110 MHz

While sharing between IMT-2000 and SATOPS is feasible during an extended period, a migration of SATOPS to the 2025-2110 MHz band is feasible and beneficial to both DoD and IMT-2000. Migrating to the 2025-2110 MHz band will ensure that DoD operations are consistent with similar operations conducted around the world and will ensure that DoD is not subject to interference from the rapidly increasing use of the 1710-1850 MHz band for commercial mobile operations on a global scale. A migration to the 2025-2110 MHz band should be conducted as existing satellites, which cannot be retuned from the 1742-1861 MHz band, are replaced.

Conventional Fixed Microwave Communications Systems

The NTIA interim report states that numerous federal agencies, including DoD, United States Department of Agriculture, Department of the Interior, U.S. Coast Guard, Department of Justice, and the Department of Energy, have conventional fixed operations in the 1710-1850 MHz band.[17]

1710-1755 MHz - As a result of the Balanced Budget Act of 1993, the 1710-1755 MHz portion of the 1710-1850 MHz band was reallocated for non-government use and most of the conventional fixed point-to-point links operating in this portion of the band have been, or will be, relocated. Certain systems, however, are exempt from

[17] NTIA interim report at 14-15.

reallocation.[18] This includes fixed microwave stations used by Federal Power Agencies (FPAs), and certain fixed stations involving safety-of-life operations.

1755-1850 MHz – The NTIA interim report states that there are 3836 assignments for fixed services in the 1755-1850 MHz band.[19] Interference will occur between IMT-2000 and conventional fixed operations in a relatively limited area around each fixed facility. However, due to the widespread deployment of conventional fixed operations, it is not feasible for a ubiquitous mobile service, such as IMT-2000, to share with conventional fixed operations. Accordingly, either band segmentation or full relocation of the conventional fixed services is necessary if IMT-2000 is to be accommodated. The advantages of and mechanisms for relocation are described below.

1) *Advantages of relocation*

Many of the Federal Government communications systems are analog systems that have been in use for many years. Relocation provides an opportunity to upgrade the quality and reliability of these systems to more efficient digital operations. As noted in the NTIA report, aging analog equipment operating in the 1710-1850 MHz band will eventually require replacement. However, due to the reallocation of services from the band, there is no digital equipment available to replace the existing systems in this band.[20] Some Federal users, such as the U.S. Coast Guard and the Department of Justice, have already begun to transition fixed operations into higher frequency bands.[21] Relocation as part of an effort to provide spectrum for IMT-2000 provides an opportunity for Federal users to be fully compensated for the cost of relocation.

2) *Relocation of Fixed services*

There are several viable options for relocation of fixed services that should be considered in the following order. As fully described in a contribution to the Association Group, it appears to be feasible to relocate all of the conventional fixed operations to other frequency bands or satisfy the communications requirements through other means. Methods of relocation should be considered as follows:

a) *Relocation to Alternative Media or Other Commercial Services*

The use of alternative media may be an attractive means of satisfying the requirements of the affected agency without the use of fixed microwave. The use of commercially available services may also be cost effective. As a result, the preferred option for relocation of Federal fixed microwave systems in the 1710-1850 MHz band should be to move such systems to alternative media or other commercial services.

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[18] *Reallocation Final Report,* Appendix E.

[19] NTIA interim report at 14.

[20] NTIA interim report at 24.

[21] NTIA interim report at 23.

b) Relocation to Federal Government Bands

If it is not practicable to use alternative media or other commercial services, the affected systems should be relocated to available spectrum that is allocated to the Federal Government on an exclusive-use basis. This will provide the agencies with the maximum flexibility in accommodating the affected systems without the need to coordinate with the private sector. The following bands have been identified for consideration:

4400-4990 MHz
7250-8400 MHz

These bands are currently available for Government fixed operations and should be the first frequency bands considered for relocation.

c) Relocation to Non-Federal Government Bands

If alternative spectrum cannot be found in bands allocated to the Federal Government, the U.S. Government should consider relocating these affected Federal systems to bands that are allocated for non-Federal use. In this case, it will be necessary to review regulatory issues associated with Federal agencies using non-Federal bands. The following bands have been identified for consideration:

3700-4200 MHz
5925-6425 MHz
6525-6875 MHz
6875-7075 MHz
7075-7125 MHz
10.55-10.68 GHz
10.7-11.7 GHz

Tactical Radio Relay

Tactical Radio Relay systems are similar to conventional fixed systems, except that they operate on a transportable basis. Similar to conventional fixed systems, interference between IMT-2000 and tactical radio relay will occur in a localized area around the tactical radio relay system. All of the tactical radios described in the NTIA and DoD interim reports are capable of operating over a large amount of spectrum, ranging from 1350-1850 MHz for current systems to 1350-2690 MHz for new systems and tuning to channels centered every 125 kHz in this range. However, in its interim report, DoD states that MSE systems rarely have access to spectrum outside of 1350-1390 MHz and 1710-1850 MHz and that the DWTS systems typically use the 1350-1390 MHz, 1432-1435 MHz, and 1710-1850 MHz bands.[22]

During discussions at the Association Group's meetings, requirements for tactical radio relay operations were described as very heavy during the largest scale military training operations with declining requirements for smaller scale operations. The NTIA

[22] DoD interim report at D-2 – D-4.

interim report provides information on the location of training areas in which tactical radio relay systems operate, but does not provide detailed information on the operational aspects, such as the frequency or size of training operations at each location. It is reasonable to assume, however, that the largest scale training exercises would be conducted in the most remote areas, where a large deployment of troops have the room required to maneuver, whereas training closer to more suburban areas would be limited to a smaller deployment of troops. Accordingly, it is reasonable that the military requirements for tactical radio relay are greatest in very remote areas and are increasingly modest in areas closer to major population centers where one would expect smaller troop deployments.

Considering the above assumptions, it is feasible to develop a plan for sharing between 3G systems and tactical radio relay systems that provides access to most or all of the spectrum in the 1710-1850 MHz band for 3G systems in urban areas, where demand or commercial services is greatest and provides spectrum for military training with increasing amounts available in progressively rural areas as 3G demand decreases and the military requirements increase.

Under this approach, if each 3G licensee has access to 2x15 MHz of spectrum, it is feasible for DoD to use 2x5 MHz in training areas located outside of major urban centers where 3G spectrum requirements are reduced. For military bases located in very remote areas, it is possible for DoD to use 2x10 MHz of a licensees' spectrum. Accordingly, even if the entire 1710-1850 MHz band were made available immediately for use by IMT-2000, it is possible for DoD to have access to the majority of the band for its tactical radio relay requirements in training areas where its needs are greatest, while still providing sufficient capacity for IMT-2000 to meet the demand for service. It will be necessary to conduct a more detailed investigation of the exact requirements at the various training areas.

In addition to the above geographic approach to sharing spectrum in the 1710-1850 MHz band, to the extent that spectrum at 1710-1850 MHz is paired with spectrum in another band, it is also reasonable for DoD to use the portion of the pair outside of 1710-1850 MHz. This will provide DoD access to additional spectrum in rural areas.

The above sharing mechanism requires prior agreement as to which channels would be used by DoD, in order to ensure that all of an IMT-2000 licensee's spectrum is not used by DoD in an area. An example of how such an approach could work is provided below in Figure 1.

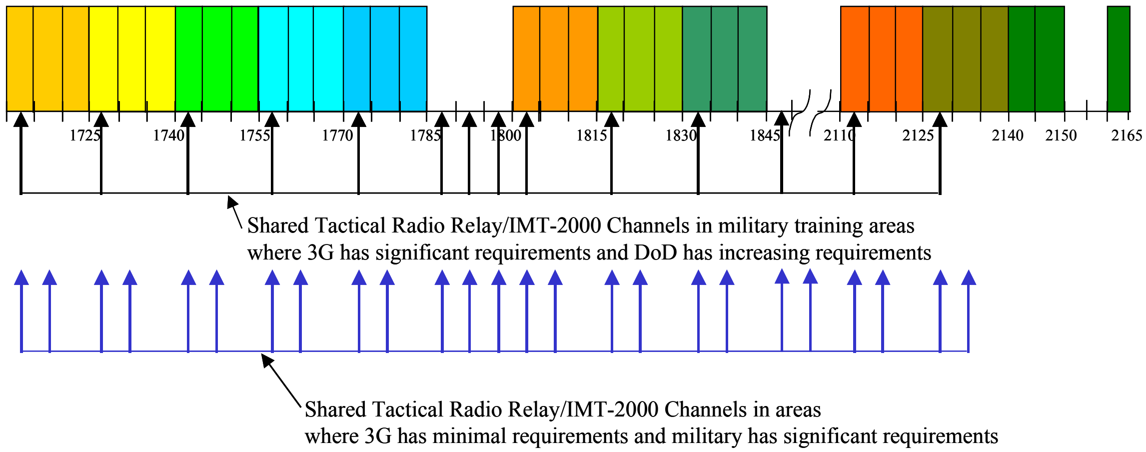

Figure 1: Example of shared use between IMT-2000 and Tactical Radio Relay.

The above approach provides DoD with access to almost as much spectrum as they currently have in rural areas, while providing IMT-2000 access to sufficient spectrum to meet its requirements in a variety of operating environments, ranging from dense urban to rural. In developing sharing rules for this approach, guidelines should be established so that DoD users first select channels in bands not used for IMT-2000, or in IMT-2000 guardbands. As additional channels are required, DoD users would then use shared channels.

To the extent that tactical radio relay systems have the capability to tune to channels in frequency bands currently available only to non-Government users, the FCC also should consider sharing rules that allows Government users access to these bands in geographic areas where non-Government requirements are minimal. Such access could be through strict regulatory sharing arrangements or through more flexible approaches such as those being considered in the Commission's proceeding addressing secondary markets.[23]

Air Combat Training Systems

Air Combat Training Systems (ACTS) are used for training combat flight crews. Because ACTS operate from airborne platforms, interference to and from 3G systems will extend over a very large geographic area thereby making it infeasible for ACTS and 3G systems to share on a geographic basis.

As described in the DoD interim report, the current ACTS systems, the Navy Tactical Air Combat Training System (TACTS) and the Air Force Air Combat Maneuvering Instrumentation (ACMI) use two frequencies, 1840 and 1830 MHz, to transmit from a ground station to the aircraft and use two frequencies, 1788 and 1778 MHz, to transmit from the aircraft to the ground station. In addition, there is a ground network to facilitate the flow of information. The distribution of these channels makes it unlikely that a band

[23] *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, Notice of Proposed Rule Making, WT Docket 00-230, released November 27, 2000, FCC 00-42.

segmentation sharing plan could be devised that would accommodate both 3G systems operating throughout the 1710-1850 MHz band and the TACTS and ACMI systems.

Both the DoD and NTIA interim reports indicate that the current ACTS systems are scheduled for replacement by the Joint Tactical Combat Training System (JTCTS).[24] JTCTS is a spread spectrum system that provides additional flexibility and capabilities for training operations. As described in the DoD interim report, JTCS consists of three components, a primary air-to-air link, a secondary ground-to-air link, and a tertiary point-to-point ground link. The DoD report indicates that the tertiary point-to-point link could be operated in another frequency band similar to relocating other fixed point-to-point systems.[25]

JTCTS is capable of operating in two modes, a narrowband mode and a wideband mode. Pursuant to discussion in the Association Group meetings, the wideband mode is generally only required for uses over water where multipath reflections require greater systems processing gain. Over the Continental United States (CONUS), operation in the narrowband mode, which has a bandwidth of 5.63 MHz at the 20 dB roll off point, and 2.1 MHz wide at the 3 dB roll off point, using two channels, should be sufficient to support training operations. Additional channels may be required to support separate training operations in adjacent geographic areas. However, in no case should more than 4 channels be required over CONUS. These channels are narrow enough that it is feasible to operate them in spectrum that would be guardband spectrum for 3G systems. An example of one such sharing arrangement is illustrated below in **Figure 2**.

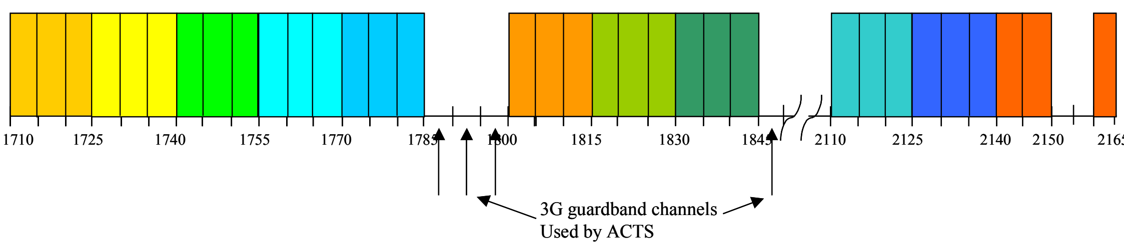

Figure 2: Use of guard bands by ACTS.

Based on the general approach presented above, band segmentation sharing between JTCTS and 3G is feasible.[26] To facilitate this, DoD should continue to migrate its existing ACTS systems to the more advanced JTCS. The current JTCS receiver design is an inefficient one that does not adjust to the narrowband transmitter operation. Instead it is always open to receiving interference over a wideband 22.5 MHz channel. Such a design would result in interference into JTCTS from IMT-2000, using the above approach to sharing. Additional filtering must be added to the JTCTS receivers to increase its efficiency and avoid interference from 3G operations.

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[24] DoD interim report at E-1; NTIA interim report at 25

[25] DoD interim report at E-22

[26] Additional analysis is required to determine the effect of adjacent channel emissions on both JTCTS and 3G systems.

The 2500-2690 MHz Band

There was considerable discussion in the Association Group meetings regarding the use of the 2500-2690 MHz band to accommodate 3G services. The group addressed the potential for sharing the band among ITFS/MDS and 3G users, and concluded that co-channel sharing is not possible. The group also addressed the possible segmentation of the band to accommodate 3G services, but did not reach consensus on the feasibility of this option. It did, however, make several recommendations for further FCC review. First, the Commission should further investigate the current and planned uses of the band for commercial and educational purposes by ITFS and MDS incumbents. Second, the Commission should determine whether alternate spectrum is available to accommodate the relocation of incumbent systems and what specific technical and economic impacts relocation would have on incumbents. Third, the Commission should determine whether more flexible service rules and secondary market mechanisms would facilitate the use of the band for 3G services.

Industry Working Group on 3G Characteristics

Report

Characteristics of International Mobile Telecommunications (IMT) 2000 Technology

Chair: Gerry Flynn

20 February 2001

Executive Summary

The goal of this industry group is to review/update the 3G system characteristics in order to ensure that the characteristics utilized for the analysis of sharing between IMT-2000 and other systems represent the most accurate information of 3G systems. Attached below is the table of characteristics that represent the current systems, much of this information is the same as found in ITU-R Recommendation 1457 “Detailed specifications of the radio interfaces of international mobile telecommunications-2000 (IMT-2000)”. This recommendation in turn points to the approved standards that have been developed by the appropriate standards bodies.

Table 1. Characteristics of IMT-2000 Mobile Stations

Parameter	CDMA-2000 1X	CDMA-2000 3X	UWC-136 (TDMA)[l,**] EDGE		TD-CDMA [21,22,23,24]	W-CDMA [23]
Carrier Spacing	1.25 MHz	3.75 MHz	30 kHz [14]	200 kHz [7]	5 MHz (nominal)	5 MHz +/- n*0.2MHz [6]
Duplex Method	FDD	FDD	FDD	FDD	TDD	FDD
Transmitter Power, (typical)	100 mW	100 mW	100 mW	100 mW	100 mW	100mW
Transmitter Power, (maximum)	250mW	250mW	1 W [15]	1 W [8]	250 mW	250 mW or 125mW [1]
Antenna Gain	0 dBi	0 dBi	0 dBi	0 dBi	0 dBi	0 dBi
Antenna Height	1.5 m	1.5 m	1.5 m	1.5 m	1.5 m	1.5 m
Access Techniques	CDMA	CDMA	TDMA [15]	TDMA[m]	TDMA/CDMA	CDMA[j]
Data Rates Supported	153.6 kbps (standard supports up to 625.35 kbps on forward link and up to 433.35 on reverse link)kbps	460.8 kbps (standard supports up to 2084.55. kbps on forward link and up to 1354.95 on reverse link)kbps	13.0 kbps (π/4 DQPSK) 19.95 kbps (8-PSK downlink) 18.6 kbps (8-PSK uplink)	144 kbps [9] 384 kbps	Pedestrian: 144 kbps Vehicular: 384 kbps Indoors: 2 Mbps	Pedestrian: 144 kbps Vehicular: 384 kbps Indoors: 2 Mbps
Modulation Type	QPSK/BPSK	QPSK/BPSK	π/4-DQPSK 8-PSK	GMSK 8-PSK	QPSK	HPSK[o]
Emission Bandwidth	1250 < |f – fc| < 1980 kHz, -42 dBc in 30 kHz; 1980 < |f – fc|, -50 dBc in 30 kHz;	2,5 MHz < |f – fc| < 2.7 MHz, -14 dBm in 30 kHz; 2,7 MHz < |f – fc| < 3.5 MHz, -(14+15(f-fc-2.7 MHz)) dBm in 30 kHz; 3.5 MHz < |f – fc| < 7.5 MHz, -(13+(f-fc-3.5 MHz)) dBm in 1 MHz; 7.5 MHz < |f – fc| < 8.5 MHz, -(13+10(f-fc-7.5 MHz)) dBm in 1 MHz; 8.5 MHz < |f – fc| -27 dBm in 1 MHz	See [17]		cf. Section 6.6 of [21]	See [4]
-3 dB				0.12 MHz [10], 0.12 MHz [11]		

** UWC-136 consists of three components: enhancements to the 30 kHz channels (designated as 136+) for advanced voice and data capabilities, a 200 kHz carrier component for high speed data (384 kbit/s) accommodating high mobility (designated as 136HS Outdoor), and a 1.6 MHz carrier component for very high speed data (2 Mbit/s) in low mobility applications (designated as 136HS Indoor). The combined result constitutes the IMT-2000 Radio Interface referred to as UWC-136.

Parameter	CDMA-2000 1X	CDMA-2000 3X	UWC-136 (TDMA)[l**] EDGE		TD-CDMA [21,22,23,24]	W-CDMA [23]
-20 dB				0.18 MHz [10], 0.18 MHz [11]		
-60 dB				0.40 MHz [10], 0.60 MHz [11]		
Receiver Noise Figure, (worst case)	9 dB	9 dB	9 dB	9 dB	9 dB	9 dB
Antenna Temperature, (kTb)[g]			-128 dBm [b]	-121 dBm [b]	-108 dBm in 3.84 MHz	-108 dBm[i]
Receiver Thermal Noise Level	125. dBm[a] -113 dBm -104 dBm[b]	-125 dBm[a] -108 dBm -99 dBm[b]	-119 dBm	-112 dBm	-99 dBm/3.84 MHz	-99 dBm
Receiver Bandwidth			See [18]	See [12]	Unavailable, < 5 MHz	See [5]
-3 dB						
-20 dB						
-60 dB						
E_b/N_o for $P_e = 10^{-3}$	4 dB for 1% FER for 9600 bps speech services 1.9 dB for 1%FER in AWGN 3.9 dB for 5% FER in slow fading channel (nominal supported rate)	performance not available	7.8 dB	8.4 dB	3 dB (single antenna, equivalent rate ½ code)	3.1 dB*
Receiver Sensitivity[c]	-104 dBm **Total** received power in fully loaded system. Single 9600 bps traffic channel is at –119.6 dBm in AWGN for 1% FER	-99 dBm **Total** received power in fully loaded system Single 9600 bps traffic channel is at –119.6 dBm in AWGN for 1% FER	-113 dBm [19]	-102 dBm [9]	-105 dBm (cf. Table 7.2, [21])	-106 dBm See [3] [k]
Interference Threshold 1[d]	-110 dBm in 1.25 MHz	-105 dBm in 3.75 MHz	No equivalent	See [13]	-111 dBm in 3.84 MHz	-105dBm[f]
Interference Threshold 2[e]	-94 dBm in 1.25 MHz	-90 dBm in 3.75 MHz	No equivalent	See [13]	-92 dBm in 3.84 MHz	-89 dBm[f]

[a]in bandwidth equal to data rate : for 1x and 3x CDMA2000, values are given for 9600 bps speech services and nominal supported rate (153.6 kbps) for data services.

[b]in receiver bandwidth
[c]For a 10^{-3} raw bit error rate, theoretical E_b/N_o
[d]Desired signal at sensitivity, I/N = -6 dB for a 10 percent loss in range
[e]Desired signal 10 dB above sensitivity, S/(I+N) for a 10^{-3} BER
[f] Let N = receiver thermal noise = -99 dBm for WCDMA.Let S = receiver sensitivity = -106 dBm for WCDMA. See also explanatory note [f] in Table 2

[g] 10Log(kTb) + 30 (dBm), where k = Boltzman's constant = 1.38e-23, T = reference temperature = average Earth temperature = 277 K, b = noise equivalent bandwidth (Hz).

[h] The above antenna temperature plus the worst-case receiver noise figure.

[i] b = chip rate = 3.84e6 chips/sec.

[j] Chip rate = 3.84e6 chips/sec.

[k] Reference sensitivity for bit error ratio (BER) not to exceed 10e-3 for specified values of energy per chip (Ec) = -117 dBm and received power spectral density (Ior) = -107 dBm measured at mobile station antenna connector.

[l] A nominal operational frequency band of 1900 MHz is assumed.

[m] TDMA, comprising 8 timeslots (577 us) per single TDMA frame (4.615 ms). For user packet data service, 1-4 timeslots per frame may be used by mobile stations having multi-slot classes that do not require simultaneous transmission and reception, i.e. classes for which a duplexer is not required.

[n] Data rate on a per-timeslot basis.

[o] Hybrid Phase Shift Keying: a method peculiar to UMTS WCDMA in which the peak to average ratio is reduced in comparison to a QPSK signal by mixing the orthogonal variable spreading factor (OSVF) with both information sources as real signals, i.e. those destined for I and Q modulation components, and then shifting one component by 90 degrees to produce an equivalent imaginary signal and then utilizing gain control on the Q channel to preserve orthogonality.

* Assumes Eb/No for Pe = 10E-6 without diversity

Table 2. Characteristics of IMT-2000 Base Stations

Parameter	CDMA-2000 1X	CDMA-2000 3X	UWC-136 (TDMA)** EDGE		TD-CDMA [21,22,23,24]	W-CDMA [23]
Operating Bandwidth	1.25 MHz	3.75 MHz	30 kHz	200 kHz	5 MHz (nominal)	5 MHz +/- n*0.2MHz
Duplex Method	FDD	FDD	FDD	FDD	TDD	FDD
Transmitter Power	10 W	10 W	10 W	10 W	10 W	10 W
Antenna Gain	17 dBi per 120 deg. sector	17 dBi per 120 deg. sector	17 dBi per 120 deg. sector	17 dBi per 120 deg. sector	17 dBi per 120 deg. sector	17 dBi per 120 deg. sector
Antenna Height	40 m	40 m	40 m	40 m	40 m	40 m
Tilt of Antenna	2.5 degs down	2.5 degs down	2.5 degs down	2.5 degs down	2.5 degs down	2.5 degs down
Access Techniques	CDMA	CDMA	TDMA	TDMA	TDMA/CDMA	CDMA
Data Rates Supported	153.6 kbps (standard supports up to 625.35 kbps on forward link and up to 433.35 on reverse link)	460.8 kbps (standard supports up to 2084.55. kbps on forward link and up to 1354.95 on reverse link)	30 kbps 44 kbps	384 kbps	Pedestrian: 144 kbps Vehicular: 384 kbps Indoors: 2 Mbps	Pedestrian: 144 kbps Vehicular: 384 kbps Indoors: 2 Mbps
Modulation Type	QPSK/BPSK	QPSK/BPSK	π/4-DQPSK 8-PSK	GMSK 8-PSK	QPSK	QPSK
Emission Bandwidth	885 < |f – fc| < 1250 kHz, -45 dBc in 30 kHz; 1250 < |f – fc| < 1980 kHz, min (-45 dBc in 30 kHz, -9dBm in 30 kHz); 1980 < |f – fc| < 2250 kHz, -55 dBc in 30 kHz; 2250 < |f – fc, -13 dBm in 1 MHz				cf. Section 6.6.2 of [22]	
-3 dB			0.03 MHz	0.18 MHz		3 GPP
-20 dB			0.03 MHz	0.22 MHz		TS25.104
-60 dB			0.04 MHz	0.24 MHz		
Receiver Noise Figure, (worst case)	5 dB	5 dB	5 dB	5 dB	5 dB	5 dB
Receiver Thermal Noise Level	-129 dBm -117dBm[a] -108 dBm[b]	-129 dBm -112 dBm[a] -103 dBm[b]	-125 dBm[a]	-117 dBm[a]	-113 dBm at 384 kbps	-113 dBm in 384 kbps
Receiver Bandwidth					Unavailable, < 5 MHz	
-3 dB			0.03 MHz	0.18 MHz		Reference
-20 dB			0.04 MHz	0.25 MHz		Reference
-60 dB			0.09 MHz	0.58 MHz		Reference

** UWC-136 consists of three components: enhancements to the 30 kHz channels (designated as 136+) for advanced voice and data capabilities, a 200 kHz carrier component for high speed data (384 kbit/s) accommodating high mobility (designated as 136HS Outdoor), and a 1.6 MHz carrier component for very high speed data (2 Mbit/s) in low mobility applications (designated as 136HS Indoor). The combined result constitutes the IMT-2000 Radio Interface referred to as UWC-136.

Parameter	CDMA-2000 1X	CDMA-2000 3X	UWC-136 (TDMA)** EDGE		TD-CDMA [21,22,23,24]	W-CDMA [23]
E_b/N_o for $P_e = 10^{-3}$	6.0 dB for 0.3% FER for 9600 bps speech services in AWGN. 4.9 dB for 2.4% FER in AWGN, 4.3 dB for 2.5% FER in slow fading for nominal supported rate	performance not available	7.8 dB	8.4 dB	3 dB (single antenna, equivalent ½ rate code)	3.4 dB*
Receiver Sensitivity[c]	-119 dBm for Fundamental channel in AWGN	-119 dBm for Fundamental channel in AWGN	-117 dBm	-108.Bm	-109 dBm (cf. Table 7.1 of [22])	-110 dBm
Interference Threshold 1[d]	-114 dBm in 1.25 MHz	-109 dBm in 3.75 MHz	-131 dBm	-123 dBm	-115 dBm in 3.84 MHz	See note [f]
Interference Threshold 2[e]	-98 dBm in 1.25 MHz	-93 dBm in 1.25 MHz	-115 dBm	-107dBm	-96 dBm in 3.84 MHz	See note [f]

[a]in bandwidth equal to data rate : for 1x and 3x CDMA2000, values are given for 9600 bps speech services and nominal supported rate for data services.

[b]in receiver bandwidth

[c]For a 10^{-3} raw bit error rate, theoretical E_b/N_o

[d]Desired signal at sensitivity, I/N = -6 dB for a 10 percent loss in range

[e]Desired signal 10 dB above sensitivity, S/(I+N) for a 10^{-3} BER

[f] The thermal noise figure for a W-CDMA receiver is –108dBm based on kTf where k is Boltzmann's constant (1.38E-23), T is the temperature in Kelvin and f is the bandwidth in Hertz. For a noise figure of 4dB (typical value for a base station receiver), the thermal noise becomes –104dBm. However receiver sensitivity depends on the service (voice, packet etc.). For example, the voice (DTCH 32) sensitivity for the base station receiver is –121 dBm for BER < 0.001

* Assumes Eb/No for Pe = 10E-6 without diversity

Table 3. IMT-2000 Traffic Model Characteristics[a]

Parameter	Value
Traffic Environments	Rural Vehicular Pedestrian In-building (Central business district)
Maximum Data Rates	Rural - 9.6 kbps Vehicular - 144 kbps Pedestrian - 384 kbps In-building - 2 Mbps
Cell Size	Rural - 10 km radius Vehicular - 1000 m radius Pedestrian - 315 m radius In-building - 40 m radius
Users per cell during busy hour	Rural - not significant Vehicular - 4700 Pedestrian - 42300 In-building - 1275
Percent of total uplink traffic >64 kbps during busy hour	Rural - not significant Vehicular - 34% Pedestrian - 30% In-building - 28%
Percent of total downlink traffic >64 kbps during busy hour	Rural - not significant Vehicular - 78% Pedestrian - 74% In-building - 73%
Average number of users per cell per MHz during busy hour assuming frequency duplex operation	Rural - not significant Vehicular < 64 kbps - 16 > 64 kbps - 4 Pedestrian < 64 kbps - 150 > 64 kbps - 64 In-building < 64 kbps - 4 > 64 kbps - 2

[a] Values in the table are for a mature network.

Table 4. Rate of IMT-2000 Network Development[a]

	Calendar Year		
Local Environment	2003	2006	2010
Urban	10%	50%	90%
Suburban	5%	30%	60%
Rural	0%	5%	10%

[a] For some interactions the potential for interference will be influenced by the degree to which IMT-2000 networks are built out. Table 4 identifies assumptions that will be used in the assessments with respect to the degree to which US IMT-2000 networks are developed following the granting of licenses. The levels of aggregate emissions for a fully mature IMT-2000 environment will be taken from ITU-R 687.2 or other reference material as appropriate.

References:

[1] "3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; UE Radio Transmission and Reception", (3G Technical Specification 25.101), clause 6.2.1. User equipment (UE) power specified for power class II and III.

[2] "3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; UE Radio Transmission and Reception", (3G Technical Specification 25.101), clause 8.3.1.

[3] "3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; UE Radio Transmission and Reception", (3G Technical Specification 25.101), clause 7.3.1.

[4] "3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; UE Radio Transmission and Reception", (3G Technical Specification 25.101), clause 6.6.2.1.1:

The power of any UE emission shall not exceed the levels specified in Table 6.10

Table 6.10: Spectrum Emission Mask Requirement

Frequency offset from carrier Δf	Minimum requirement	Measurement bandwidth
2.5 - 3.5 MHz	-35 -15*(Δf – 2.5) dBc	30 kHz *
3.5 - 7.5 MHz	-35- 1*(Δf-3.5) dBc	1 MHz *
7.5 - 8.5 MHz	-39 - 10*(Δf – 7.5) dBc	1 MHz *
8.5 - 12.5 MHz	-49 dBc	1 MHz *

[5] "3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; UE Radio Transmission and Reception", (3G Technical Specification 25.101), clause 7.6.1:

The BER shall not exceed 0.001 for the parameters specified in Table 7.6 and Table 7.7. For Table 7.7 up to (24) exceptions are allowed for spurious response frequencies in each assigned frequency channel when measured using a 1 MHz step size.

Table 7.6: In-band blocking

Parameter	Unit	Offset	Offset
DPCH_Ec	dBm/3.84 MHz	-114	-114
$\hat{I}_{or}$	dBm/3.84 MHz	-103.7	-103.7
$I_{blocking}$ (modulated)	dBm/3.84 MHz	-56	-44
F_{uw} (offset)	MHz	+10 or –10	+15 or –15

NOTE definitions:

$DPCH\_E_c$	Average energy per PN chip for DPCH.
$\hat{I}_{or}$	The received power spectral density of the down link as measured at the UE antenna connector.

[6] "3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; UE Radio Transmission and Reception", (3G Technical Specification 25.101), clause 5.4.1.

[7] "RF Minimum performance requirements 136HS Outdoor and 136HS Indoor Bearers", (TR45 technical specification, TIA/EIA-136-290), clause 2.

[8] "RF Minimum performance requirements 136HS Outdoor and 136HS Indoor Bearers", (TR45 technical specification, TIA/EIA-136-290), clause 4.1.1.2. Refers to Power Class II mobile station.

[9] "RF Minimum performance requirements 136HS Outdoor and 136HS Indoor Bearers", (TR45 technical specification, TIA/EIA-136-290), clause 6.2. Specifies data rates and reference sensitivity. Reference sensitivity listed for 144 kb/s at a 10% block erasure rate (BLER).

[10] "RF Minimum performance requirements 136HS Outdoor and 136HS Indoor Bearers", (TR45 technical specification, TIA/EIA-136-290), Table A3a: Modulation and noise spectrum mask due to GMSK modulation. Measurement bandwidth is 30 KHz.

[11] "RF Minimum performance requirements 136HS Outdoor and 136HS Indoor Bearers", (TR45 technical specification, TIA/EIA-136-290), Table A3b: Modulation and noise spectrum mask due to 8-PSK modulation. Measurement bandwidth is 30 KHz.

[12] "RF Minimum performance requirements 136HS Outdoor and 136HS Indoor Bearers", (TR45 technical specification, TIA/EIA-136-290), clause 5.1:

The mobile station shall meet the requirements set forth in clause 6.2 in the presence of an unmodulated carrier at the following frequencies and amplitudes:

Frequency of blocking signal	Amplitude of blocking signal
600 KHz <= $|f - f_0|$ < 800 KHz	-43 dBm
800 KHz <= $|f - f_0|$ < 1.6 MHz	-43 dBm
1.6 MHz <= $|f - f_0|$ < 3 MHz	-33 dBm
3 MHz = $|f - f_0|$	-26 dBm

[13] "RF Minimum performance requirements 136HS Outdoor and 136HS Indoor Bearers", (TR45 technical specification, TIA/EIA-136-290), clause 6.3:

In the following table the reference co-channel interference (C/Ic), Block Error Rate (BLER) performance is defined for each of the channel conditions. The actual interference ratio is defined as the interference ratio for which this performance is met. The actual interference ratio shall be less than a specified limit, called the reference interference ratio. For 200 kHz bearers the reference interference ratio shall be, for BTS and all types of MS:

Table 1a: Input signal level and interference ratio for Outdoor BTS at reference performance

Bearer	Environment	Speed km/hr	Coding Scheme	Error Rate	C/I (dB)
136HS Outdoor	Pedestrian A	3	GCS-1	10% BLER	7
136HS Outdoor	Pedestrian A	3	GCS-2	10% BLER	8.5
136HS Outdoor	Pedestrian A	3	GCS-3	10% BLER	9.5
136HS Outdoor	Pedestrian A	3	GCS-4	10% BLER	13.5
136HS Outdoor	Pedestrian A	3	PCS-1	10% BLER	13
136HS Outdoor	Pedestrian A	3	PCS-2	10% BLER	16
136HS Outdoor	Pedestrian A	3	PCS-3	10% BLER	18
136HS Outdoor	Pedestrian A	3	PCS-4	10% BLER	19.5
136HS Outdoor	Pedestrian A	3	PCS-5	10% BLER	21
136HS Outdoor	Pedestrian A	3	PCS-6	10% BLER	24.5
136HS Outdoor	Vehicular A	50	GCS-1	10% BLER	3.5
136HS Outdoor	Vehicular A	50	GCS-2	10% BLER	7
136HS Outdoor	Vehicular A	50	GCS-3	10% BLER	8.5
136HS Outdoor	Vehicular A	50	GCS-4	10% BLER	17
136HS Outdoor	Vehicular A	50	PCS-1	10% BLER	9
136HS Outdoor	Vehicular A	50	PCS-2	10% BLER	13
136HS Outdoor	Vehicular A	50	PCS-3	10% BLER	14.5
136HS Outdoor	Vehicular A	50	PCS-4	10% BLER	18
136HS Outdoor	Vehicular A	50	PCS-5	10% BLER	21
136HS Outdoor	Vehicular A	50	PCS-6	10% BLER	-(see note)
136HS Outdoor	Vehicular A	120	GCS-1	10% BLER	7
136HS Outdoor	Vehicular A	120	GCS-2	10% BLER	8.5
136HS Outdoor	Vehicular A	120	GCS-3	10% BLER	9.5
136HS Outdoor	Vehicular A	120	GCS-4	10% BLER	13.5
136HS Outdoor	Vehicular A	120	PCS-1	10% BLER	13
136HS Outdoor	Vehicular A	120	PCS-2	10% BLER	16
136HS Outdoor	Vehicular A	120	PCS-3	10% BLER	18
136HS Outdoor	Vehicular A	120	PCS-4	10% BLER	19.5
136HS Outdoor	Vehicular A	120	PCS-5	10% BLER	21
136HS Outdoor	Vehicular A	120	PCS-6	10% BLER	24.5

Note: This is the GMSK interfering channel. The channel models in the above table are taken directly from ITU-M1225.

[14] "Mobile Station Minimum Performance", (Technical Specification TR45, SP-4027-270b), clause 2.3.1.3.1.

[15] "Mobile Station Minimum Performance", (Technical Specification TR45, SP-4027-270b), clause 1.4 and clause 3.2.2. Refers to Power Class II mobile station.

[16] "Digital Traffic Channel Layer 1", (Technical Specification, TR45, TIA/EIA 136-131), clause 1.3.

[17] "Mobile Station Minimum Performance", (Technical Specification TR45, SP-4027-270b), clause 3.4.1.1.3.

[18] "Mobile Station Minimum Performance", (Technical Specification TR45, SP-4027-270b), clause 2.3.2.4.3:

Table 2.3.2.4.3-1 Blocking and Spurious Response Rejection [4]

Frequency Band	Desired Signal (frequency f_c)	Blocking Signal (frequency fo)	Spurious Response Limit (frequency fo)	Error Rate (%)
|fc-fo| > 3MHz (π/4 DQPSK)	-102	-30	-45	3
3MHz>|fc-fo|>90KHz (π/4 DQPSK)	-102	-45	-45	3
|fc-fo| > 3MHz (8-PSK)	-99	-30	-45	3
3MHz>|fc-fo|>90kHz (8-PSK)	-99	-45	-45	3

[19] "Mobile Station Minimum Performance", (Technical Specification TR45, SP-4027-270b), clause 2.3.1.1.3.

[20] Body Loss Expectation is that values are similar for all technologies. Footnote retained for information purposes"3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; RF System Scenarios", (3G Technical Specification 25.942), clause 4.1.1.2.

[21] "3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; UTRA (UE) TDD; Radio Transmission and Reception (Release 1999)", (Technical Specification 3GPP TS 25.102 v3.4.0 (2000-10)

[22] "3rd Generation Partnership Project; Technical Specification Group Radio Access Networks; UTRA (BS) TDD; Radio Transmission and Reception (Release 1999)", (Technical Specification 3GPP TS 25.105 v3.4.0 (2000-10)

[23] The "TD-CDMA" and "W-CDMA" air interfaces referred to in this document are standards developed by the 3G Partnership Project (3GPP). 3GPP's official designations for these air interfaces are UTRA-TDD and UTRA-FDD, respectively. Complete specifications for UTRA-TDD and UTRA-FDD are available through the 3GPP website at http://www.3gpp.org/3G_Specs/3G_Specs.htm. Series 25 of the specifications describes the UTRA-TDD and UTRA-FDD radio subsystems. A specification index is available at http://www.3gpp.org/ftp/Information/Databases/Change_Request/.

[24] TD-CDMA differs from the other air interfaces in the table in that it uses time division duplexing — uplink and downlink transmissions occur in the same spectrum, alternating in time — rather than frequency division duplexing in which uplink and downlink transmissions occur in distinct frequency blocks. In other respects, such as in-band and out-of-band emissions levels, modulation formats, etc., it is substantially similar to the other air interfaces and essentially identical to W-CDMA. TD-CDMA's coexistence behavior with a given incumbent government system (or class of systems) can therefore be assessed through the uplink and downlink coexistence behavior of W-CDMA with those system(s). It can be well approximated for coexistence calculations by treating it as a system which has the combined (worst case from a coexistence perspective) uplink and downlink coexistence behavior of W-CDMA in a single spectrum block (i.e. by combining the uplink coexistence behavior of W-CDMA in frequency block "A" with an incumbent system in block "B", and the downlink coexistence behavior of W-CDMA in frequency block "A" with an incumbent system in block "B"). At such time as the FCC may choose to make some or all of the spectrum under consideration available for commercial use, additional analyses will be required to develop a sound band plan incorporating allocations for both FDD and TDD systems. These analyses are already underway in various segments of the industry including 3GPP [20].

Industry Working Group
on Satellite Control Stations

Report

Evaluation of Sharing between International Mobile Telecommunications (IMT) 2000 Technology and Satellite Control Systems operating in the Band 1755-1850 MHz

Chair: Rob Kubik, Motorola

19 February 2001

Executive Summary

The goal of this industry group is to review and evaluate sharing between IMT-2000 operations and Satellite Control Systems (SCS) operating in the band 1755-1850 MHz. The working method of this group was to first evaluate and analyze the interference/sharing scenarios between SCS and IMT-2000. In cases where sharing on a co-frequency, co-location basis is not feasible the goal of this group is to evaluate mitigation techniques and/or discuss alternative bands for relocation of the satellite services.

This report is summarized in more detail below but initial conclusions are the following:

- **For interference from IMT-2000 operations to satellite receivers**
  - Analyses indicate that sharing is possible.
    - Methodologies are similar to that presented in DoD interim report.
    - Difference between industry analysis and DoD analyses appears to be based on initial assumptions.
  - All analyses are based on worst-case assumptions.
    - Refinement of assumptions will result in lower interference levels.
  - Existing satellite operations should not be adversely impacted through their life-span.
- **For interference from Satellite Uplink Earth Stations into IMT-2000**
  - Analysis indicates that IMT-2000 operations will suffer interference from Earth stations.
    - Actual area of interference depends on parameters, but could be more than 75 km from the location of each satellite uplink Earth station.
  - Largest impact to IMT-2000 operations is if satellite control earth station is located in populated area.
    - DoD interim report lists 10-15 Earth stations in U.S.
  - In order to mitigate interference from Earth stations it is proposed that in the short-term to relocate earth stations to remote areas.
  - In the long-term, operations can be relocated to another frequency band.
    - DoD use of 1761-1842 MHz differs from ITU standard pairing of 2025-2110 MHz uplink with 2200-2290 MHz downlink.
  - DoD operates globally - harmonization prevents spectrum conflicts outside of U.S, this is particularly important when use of the 1710-1880 MHz band outside of the U.S. is considered.

TABLE OF CONTENTS

1 Interference to Satellite Control Systems

Interference methodology and analysis results are found in Appendix A and B. These methodologies utilize the same general approach found in the DoD interim report[1] in the following respects:

- A population database is used to estimate the power radiating from an urban location.
- The power received by a satellite at a particular orbital height is the aggregation of the power radiating from all urban locations in view of the satellite.

Differences in the methodologies are:

- The parameters used to represent the power radiated by IMT-2000 systems
  - The DoD interim report utilizes values from the 1997 revision of ITU-R Recommendation 687-2[2].
  - The analysis in Appendix A and B utilizes values found in the 2000 version of ITU-R Recommendation 1457[3].
  - The difference in utilizing the different recommendations are found in Appendix E, in general the DoD approach results in up to 17 dB higher levels of interference from the same urban location.
- The DoD interim report assumes that power received is independent of orbital altitude[4].
  - Results from the analysis found in Appendix A and B indicate that this assumption results in over estimation of the interference levels of up to 30 dB.

1.1 Simulation Results

Many aspects of the methodologies found in Appendix A and B represents worst-case assumptions, a summary of some of these assumptions is found in Table 1. A more detailed analysis that would take into account some of the aspects listed in this table will result in significantly lower interference levels.

One input parameter to the methodology is a database of urban population In Table 2 results are presented based upon the population projected for the year 2015[5]. This data is utilized in order to

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[1] "Investigation of the technical feasibility of accommodating the international mobile telecommunications (IMT) 2000 within the 1755-1850 MHz band," Department of Defense IMT-2000 Technical Working Group, 27 October 2000.

[2] "International mobile yelecommuncations-2000 (IMT-2000)," ITU-R Recommendation 687-2, 1997 revision.

[3] "Detailed specifications of the radio interfaces of international mobile telecommunications-2000 (IMT-2000)," ITU-R Recommendation 1457, 2000 version.

[4] *See* DoD IMT-2000 Technical working group report, *supra* note 1 at B-2.

[5] "Urban Agglomerations, 1950-2015 (the 1996 revision)," United Nations Population Division, New York, NY, USA, 1996 (available on diskette).

represent population growth. This set contains urban populations larger than 750,000, which for this database there are a total of 431 urban locations representing a population of 1.481 billion.

In order to more closely relate results of the analysis to the DoD interim report a database from the United Nations Demographic Yearbook 1995 is utilized[6]. This database contains 3,312 major cities or urban agglomerations including capital cities and cities with more than 100,000 population. The worldwide population count for this database is 1.642 billion. Analysis results for this database are contained in Table 3. For comparison the database utilized in the DoD interim report contained 2763 urban locations and represented a population of 1.333 billion.

The results of the analysis are the peak levels indicated for each of the 4 orbital altitudes considered. It should be noted that these peak levels are generally over regions of the world where operations in the US will have none or very little contribution to the overall interference levels. This aspect shown in the tables by comparison of the peak power over CONUS and the peak power received considering all cities.

The primary factors that account for differences to the interference levels found in the DoD interim report is:

- The inclusion of a base station antenna pattern to represent variation of the power as a function of elevation.
- The assumption that the interference is independent upon the altitude of the satellite.
- The representation of the IMT-2000 system characteristics.

Table 1: Assumptions used to upper bound interference power radiating from urban location.

Assumption	Discussion
Relationship between population density and IMT-2000 penetration	Specific values utilized indicate that the number of base stations used to provide coverage in an urban location may be high.
Transmit power	The transmitter power level utilized assumes that all mobiles are at the furthest edge of the cell.
Power reduction due to small cells	Transmitter power for smaller cells is assumed to decrease as a function of cell size (R^2), typical reductions is of the order of $R^{3.5}$-R^4.
Power control	No power control is assumed.
Technology	The transmit power utilized represents only the technology with the highest power spectral density, deployment of other technology will result in lower transmit powers.
Frequency Reuse	For the base station analysis it is assumed that the frequency is reused in each sector of each cell.
System utilization	It is assumed that the worldwide distribution of IMT-2000 systems is operating at busy hour traffic levels during all times.

6 "Demographic Yearbook 1995," United Nations publication, Sales No. E/F.97.XIII.1.

Table 2: Results of interference analysis for population estimate of 2015.

Satellite Altitude	Interference from base stations				Interference from mobile stations			
	Peak Power over CONUS	Peak Received Power			Peak Power over CONUS	Peak Received Power		
		All Cities	No US	Increase due to US operations		All Cities	No US	Increase due to US operations
km	dBW/Hz	dBW/Hz	dBW/Hz	dB	dBW/Hz	dBW/Hz	dBW/Hz	dB
250	**-181.2**	-178.7	-179.0	0.3	**-186.6**	-183.8	-184.2	0.4
833	**-186.3**	-183.9	-184.2	0.3	**-193.3**	-189.3	-189.7	0.4
20200	**-201.5**	-201.5	-202.1	0.6	**-209.3**	-209.3	-209.7	0.4
35748	**-206.0**	-206.0	-206.7	0.7	**-213.5**	-213.5	-214.3	0.8

Table 3: Results of interference analysis for UN Population data of 1996.

Satellite Altitude	Interference from base stations				Interference from mobile stations			
	Peak Power over CONUS	Peak Received Power			Peak Power over CONUS	Peak Received Power		
		All Cities	No US	Increase due to US operations		All Cities	No US	Increase due to US operations
km	dBW/Hz	dBW/Hz	dBW/Hz	dB	dBW/Hz	dBW/Hz	dBW/Hz	dB
250	**-178.3**	-171.2	-171.2	0.0	**-185.0**	-182.5	-182.5	0.0
833	**-182.3**	-178.2	-178.2	0.0	**-191.2**	-187.5	-187.5	0.0
20200	**-197.0**	-196.9	-197.0	0.1	**-208.6**	-208.6	-208.9	0.3
35748	**-200.8**	-200.8	-200.9	0.1	**-212.3**	-212.3	-212.8	0.5

The impact of the interference levels indicated in Table 3 are shown in Figure 1 for the representative link budget of Table B-1 of the DoD interim report[7]. Indications are that the margin for the most sensitive satellite link will be positive. The satellite link considered is the command link with the minimum transmit power indicated in Tables B-4 through B-9 of the DoD interim report[8]. Other links such as the Carrier link and the Ranging link will have less of an impact from the interference levels computed. It should be noted that significant positive margin remains for the higher power transmissions, a potential mitigation technique for interference into IMT-2000 operations would be for the SCS systems to reduce transmit power to the minimum required to close the link. This will reduce the zone about the SCS ground stations where interference to IMT-2000 operations would experience unacceptable interference.

7 *See* DoD IMT-2000 Technical working group report, *supra* note 1 at B-4.

8 *Id.*, at B-5 through B-12.

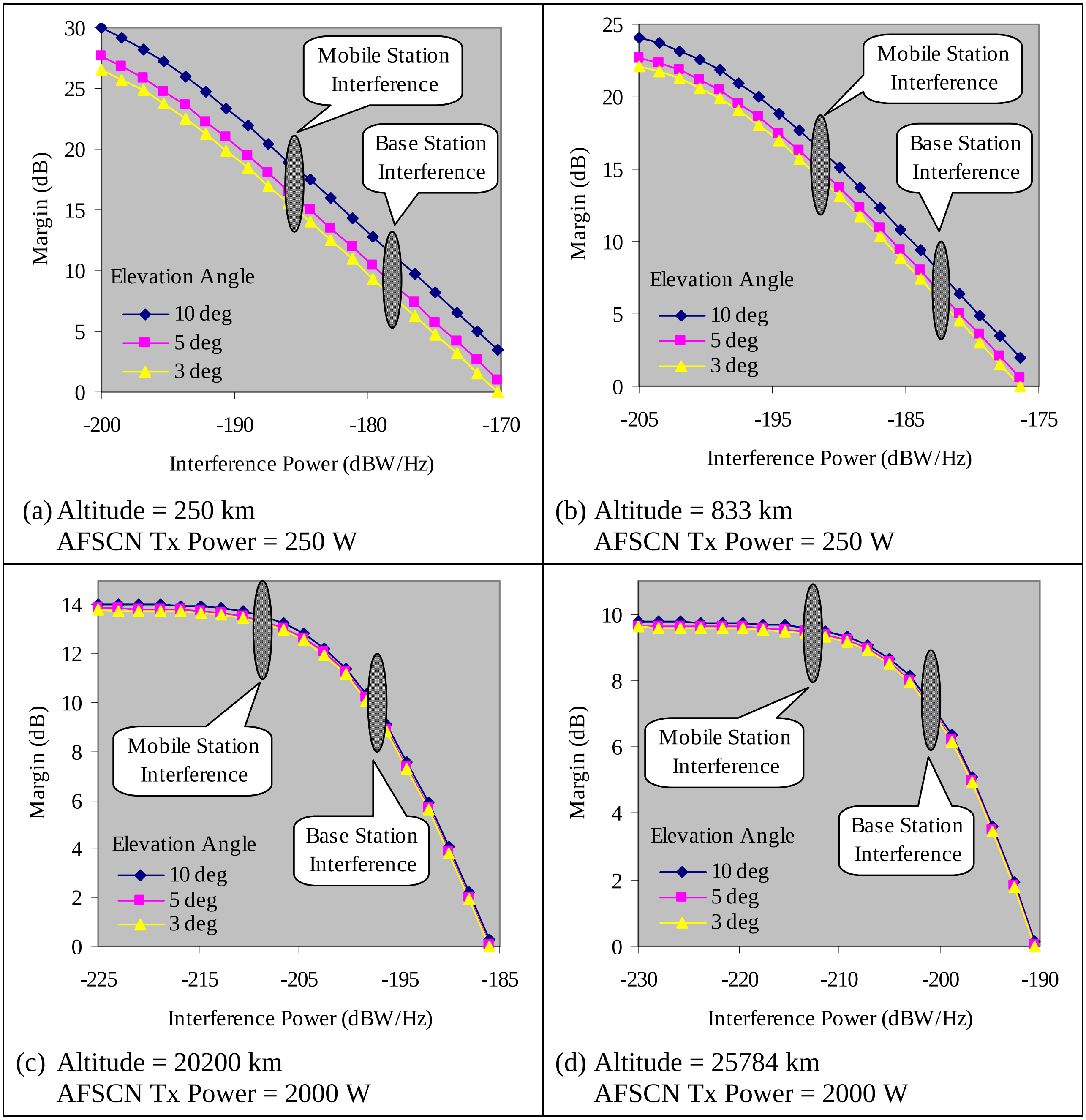

Figure 1: Summary of interference levels for the most sensitive SCS link.

2 Interference to IMT-2000 Operations

Evaluation of the impact of SCS interference into IMT-2000 systems is found in Appendix C. The evaluation calculated the elevation angles at which SCS ground station emissions exceeded IMT-2000 thresholds and approximated the percent time that these emissions occurred.

The elevation angle results shown in Table 4 indicate that SCS ground station emissions will exceed the upper threshold[9] at elevation angles lower than 20 degrees, and will exceed the lower threshold[10] at angles lower than 55 degrees under worst-case conditions. The percent time that the elevation is lower than the interference angles in Table 4 is shown in Table 5. These tables indicate that sharing between SCS ground stations and IMT-2000 systems are possible, assuming appropriate mitigation techniques are used.

This evaluation considered only IMT-2000 mobiles, however the results will be similar for IMT-2000 base stations. For sharing to be feasible, mitigation of interference from SCS ground stations would be required. Techniques that should be considered are: avoid low-elevation operations in areas containing IMT-2000 terminals, limit the times of day where low-elevation operations are performed to off-peak hours, relocate SCS ground stations to areas where IMT-2000 utilization is low, operate at minimum required transmit power, place shielding around SCS ground stations, reduce cell radius of IMT-2000 operations and incorporate baseband filtering in SCS ground stations.

Table 4: Minimum Elevation Angle for Interference

	EIRP @ 5º from boresight dBm	Power @ 25 km w/ shielding & blockage dBm	Signal at sensitivity		Signal 10 dB above sensitivity	
			Shortfall dB	Min angle for interference (topocentric) (degrees)	Shortfall dB	Min angle for interference (topocentric) (degrees)
CTS	55	-90.5	14.5	10	-	-
NHS A	67	-78.5	26.5	30	11.5	20
NHS B	55	-90.5	14.5	40	-	-
NHS DLT	55	-90.5	14.5	10	-	-
OAS	55	-90.5	14.5	Note 11	-	Note 11
ECVF	66	-79.5	25.5	55	5.5	20

Table 5: Percent of Sky Below Topographic Interference Angle

Altitude (km)	10º	20º	30º	40º	50º	55º
250	44	79	90	95	98	98
833	29	64	81	90	95	96
22200	11	32	51	66	78	84
35748	11	31	49	64	77	82

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9 Signal at 10 dB above sensitivity.

10 Signal at sensitivity.

11 No information for the OAS antenna was given in the Interim Report

3 Relocation of US Government Satellite Uplinks from the 1755 - 1850 MHz Band to the 2025 - 2110 MHz Band

Found in Appendix D is a report evaluating the feasibility of relocating the Federal Government uplink satellite control systems from the 1755 - 1850 MHz band to the 2025 - 2110 MHz band. Indications are that interference issue between Government satellite uplinks and IMT-2000 systems is the interference into the IMT-2000 systems. Possible solutions to this interference issue is the physical relocation of the Government satellite uplink earth stations to more remote areas in which IMT-2000 systems would not be as numerous or relocation of the Government satellite operations to another band. The report has analyzed the compatibility of the uplink satellite control systems with the other systems that operate in the band 2025 - 2110 MHz. The analysis has addressed the potential interference between geostationary satellite uplinks, between non-geostationary and geostationary satellite uplinks, and between non-geostationary satellite uplinks.

In the case of geostationary satellite uplinks, the analysis has shown that orbital separations of 4° are sufficient to protect the uplinks of both the existing and planned systems and the Government systems. In the case that the satellites are located closer than this and frequency separation is necessary, a search of the international filings for geostationary satellite systems has shown that the frequency usage in the band is very low. At any given orbital location, the majority of the band is unused. It has thus been concluded that coordination of the Government geostationary satellites with other geostationary satellites should not prove to be difficult.

In the case of geostationary satellite uplinks and non-geostationary satellite uplinks operating in this band, the analysis has shown that, although there is the potential to degrade the link margins of the systems, the events will be infrequent and short in duration and the systems should be able to share without putting a burden on either system. In the case of non-geostationary satellites operating with other non-geostationary satellites in the band, the conclusion reached here is that there is the potential for interference between any two systems, but the events will be infrequent and short in duration and there should be no significant problems.

With respect to the Government satellite uplinks operating with the fixed and mobile services worldwide and the Television Broadcast services within the US, it is expected that there may be some coordination that is necessary to ensure the compatible operations of these systems. However, it should be noted that these types of satellite uplinks have existed in this band and operated compatibly with these systems for many years. Thus, it is expected that these systems should be able to operate together without any significant problems.

The majority of the costs associated with relocating the Government satellite uplink operations from the band 1761 - 1843 MHz to the band 2025 - 2110 MHz will be with respect to the redesign or new construction of earth stations. For future satellites, including those that are planned, but have yet to be designed and construction has not started, it is expected that there would be essentially no difference in costs between using the lower and the higher frequency bands. There may be some time delay associated with using the higher frequency band for future satellites due to the need to develop and test the hardware that would be used on the satellites. This may impact satellites expected to be launched in the next few years, but should not cause any delays for satellites that are planned for launch two or three years from now.

For the satellites that are already in orbit or in the construction phase (past the point where frequency can be changed), there would be no possibility of moving the uplink operations with these satellites to the higher frequency band. For these systems, it may be possible to use some type of phasing plan in order to free up some of the spectrum for IMT-2000 systems. The DoD interim report notes that in some instances, satellite programs are supported via two channels in the 1761 - 1843 MHz band. This could possibly open up a portion of the spectrum for IMT-2000 systems in this band.

Since interference from Government satellite uplinks to IMT-2000 systems from satellites that cannot be relocated in frequency interference to IMT-2000 systems will be an issue for the lifetime of these satellites. A possible solution to this interference issue is the physical relocation of the Government satellite uplink earth stations to more remote areas in which IMT-2000 systems would not be as numerous. This needs further investigation to determine the impact/cost on the satellite uplink operations.

APPENDIX A: Interference Methodology to Assess Interference from Base Stations to Satellite Control Systems

1 Introduction

This contribution provides an assessment obtained by computer simulation of the interference to satellites at specific orbital altitudes from the emissions of a deployment of base stations. Section 2 describes the approach used and the assumptions made to evaluate the interference. Section 3 gives two examples of the use of this methodology for emissions from base stations.

2 Approach

Computer simulations have been used to evaluate the spatial and temporal distribution of interference to satellite systems from the emissions of a potentially large number of high density base stations to be operated in the 1.8 GHz band. The basic approach embodied in the simulation is to deploy a number of base stations in urban population centers and to then determine the interference resulting from this deployment. The simulation takes into account: the e.i.r.p. spectral density and gain of the base station transmitting station in the direction of the satellite; atmospheric absorption; path loss; and, the gain of the receiving antenna in the direction of the interfering base station.

2.1 Interference Methodology

Base stations are deployed in a cellular configuration in urban population centers to serve mobile users with communications services. For the purpose of this analysis, it is assumed that the aggregate co-channel emissions from an service area may be modeled as a single station that uses a transmitter with the power spectral density equal to the weighted sum of the power spectral density at the input to each base station in the service area, and that a single transmitting antenna provides an acceptable representation of the distribution of the e.i.r.p. spectral density above the local horizontal plane.

It has been assumed for these simulations that the aggregate emission from a single service area is proportional to the number of base stations in the urban population center.

The specific model used for the simulation is as follows. The power received from a distant transmitting station can be written as:

$$P_r = \frac{P_t G_t G_r}{l_1 l_2 l_3} \qquad (1)$$

where:

P_r = Received power spectral density at the output of an antenna in a specified frequency band (stated as a power spectral density for the purpose of this analysis (W/Hz));

P_t = Transmitted power at the input to an antenna in the same frequency band specified for received power (stated as a spectral density for the purpose of this analysis (W/Hz));

G_t = Gain of the transmitting antenna in the direction of the receiving station relative to an isotropic radiator (numeric);

G_r = Gain of the receiving antenna in the direction of the transmitting station relative to an isotropic radiator (numeric);

l_1 = Free-space propagation loss (numeric);

l_2 = Loss in excess of free-space due to several stationary and time-dependent atmospheric effects (numeric);

l_3 = Polarization coupling loss, equal to unity if the transmitting and receiving antennas are co-polarized.

The free-space propagation loss is:

$$l_1 = \left(\frac{4\pi d}{\lambda} \right)^2 \qquad (2)$$

where

d = Distance between the transmitting and receiving stations in meters

λ = Wavelength in meters.

Each co-frequency transmitting station forms a radio link to the receiver. The received power from each of the *n* links, which are assumed to be transmitting uncorrelated signals, adds to form an aggregate received power given by:

$$P_r = \sum_{i=1}^{n} \frac{P_{ti} G_{ti} G_{ri}}{l_{1i} l_{2i} l_{3i}} \qquad (3)$$

where the terms are as previously defined with the addition of a subscript, *i,* to denote each transmitting base station.

The aggregate interference is the sum of the interference from each transmitting station. The interference from each station is determined based on the transmitting and receiving antenna gains, taking into account the off axis angle of the respective antennas.

To speed the computation and taking into account that some terms are nearly constant for a single deployment area, Equation (3) is further refined as:

$$P_r = \sum_{i=1}^{m} \frac{G_{ti} G_{ri} \sum_{j=1}^{N_{bs}} P_{tij}}{l_{1i} l_{2i} l_{3i}} \qquad (4)$$

where:

i = Summation index that denotes each city;

j = Summation index that denote each base station with city i;

N_{bs} = Number of base stations in a specific deployment area; and,

m = Number of deployment areas.

Analysis of this methodology has indicated that the error introduced by the simplification in equation (4) is less than 1 dB [i].

2.2 Metropolitan Area Contribution to the Interference Power

In order to assess the contribution to the interference from any metropolitan area the deployment of cellular systems is required. Two approaches have been suggested to estimate this deployment for future years; one is based solely on the population located within a metropolitan area and the other is based upon current deployment of cellular systems. The first approach is shown in §2.2.1 and is similar to that utilized in the analysis presented by the Department of Defense IMT-2000 Technical Working Group [ii]. The second approach requires further development.

In general the system characteristics specify the maximum power supplied to the antenna of a base station. For the largest cell sizes utilized by the system this accurately represents the peak power. In areas requiring high capacity typically the cells are significantly smaller in radius, for these cases the base station transmit power should be reduced in order accurately model these areas. An approach to estimate this effect is shown in §2.2.2

2.2.1 Relationship between Population and the Base Station Density

It has been found that the geographic area of an urban population center may be related to the total population with a degree of confidence. An empirical relationship between the radius in kilometers R_p of the circular area containing a total population P is given by [iii]

$$R_p = \alpha \times P^{\beta}. \quad (5)$$

This equation has been developed from observations of settlements ranging in size from about 150 people to over a million people. For the U.S., $\alpha = 0.035$ and $\beta = 0.44$ have been found to provide satisfactory results [iii]. A comparison between the actual area and the area calculated using equation (5) for twenty of the most populous urban population centers in the U.S. is given in Table 6 (Annex A) [iv]. A manual attempt to minimize the mean-squared error for this limited set of urban population centers occurs when the coefficient is 0.0355 and the exponent is 0.44. These are remarkably close to the values found in reference [iii].

For other areas of the world, the exponent has been found to be stable while there is some variation in the coefficient. Table 7 (Annex A) shows a comparison between the actual area of eighty-five of the most populous urban population centers in the world, [v] and the area of the urban population center as calculated using equation (5) after the coefficient α has been changed to 0.015. The value of $\alpha = 0.015$ and $\beta = 0.44$ were found to minimize the mean-squared error for this data set. This corroborates the results reported in reference [iii] that a somewhat smaller value of α has been shown to apply to some other cultures that characteristically have more compact towns.

Equation (6) may be used to estimate the number of base stations of a particular size and deployment factor required to serve an area encompassing the total population. Assuming that each base station serves a circular area of radius R_h, the maximum possible number of base stations, $N(R_h)$, will be

$$N(R_h) = Int\left(\eta\left(\frac{R_p}{R_h}\right)^2 + T_{R_h}\right) \tag{6}$$

where:

$N(R_h)$ = Number of base stations for the assumed radius of the cell;

$Int(\ )$ = Indicates the integer value of the argument;

R_p = Equivalent radius of the urban area (km);

R_h = Radius of a typical BS cell (km);

η = $\eta_{R_h}\eta_p$ = Deployment factor; and,

T_{R_h} = Round off factor for cell radius R_h, valid values are $0.5 \le T_{R_h} < 1.0$.

The round off factor, T_{R_h}, ensures for cities with a small population that a cell site is located to provide coverage, possible values for cells of 315 m, 1 km and 10 km are respectfully 0.5, 0.5 and 0.9994 (the latter value ensures that cities with population as low as 850 would be covered by a 10 km cell site). The deployment factor has two aspects the first, η_{R_h}, accounts for relative number of a particular size of cell and the second, η_p, accounts for the penetration of cellular deployment in an area. To illustrate the factor η_{R_h} consider 3 cells size with a cell radius of 315 m, 1 km, and 10 km. Relationships between the sizes of the cells may be as found in Figure 1. In densely populated areas one would expect that the smaller cells would dominate the deployment and in less densely populated areas the larger cells will dominate. Note that the sum of this factor for all of the cell sizes considered must be 1.

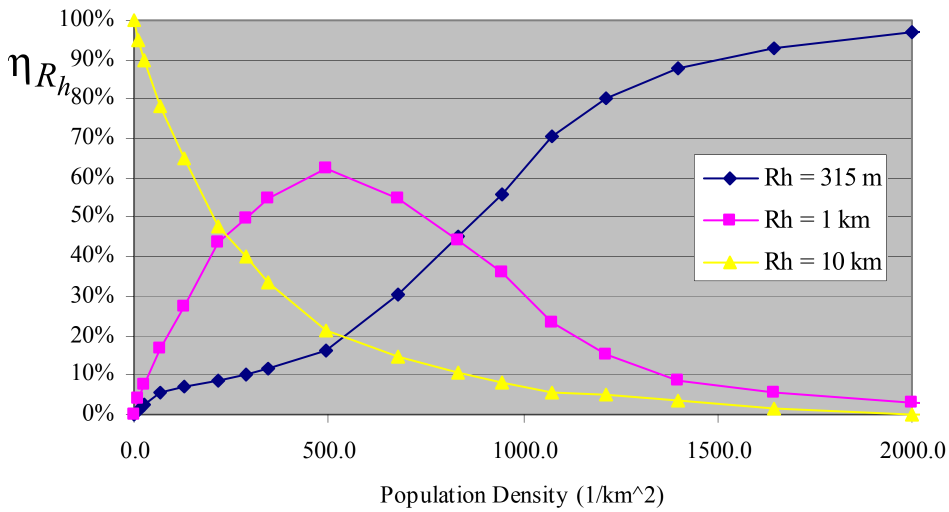


Figure 1: Example deployment factor η_{R_h} for 3 cell sizes of 315 m, 1 km and 10 km.

The factor that accounts for penetration, η_p, represents the maturity of a system in an area, values closer to 1 represent full coverage of the area and values closer to 0 represent no coverage in an area. Shown in Figure 2 is an example penetration factor for cell systems.

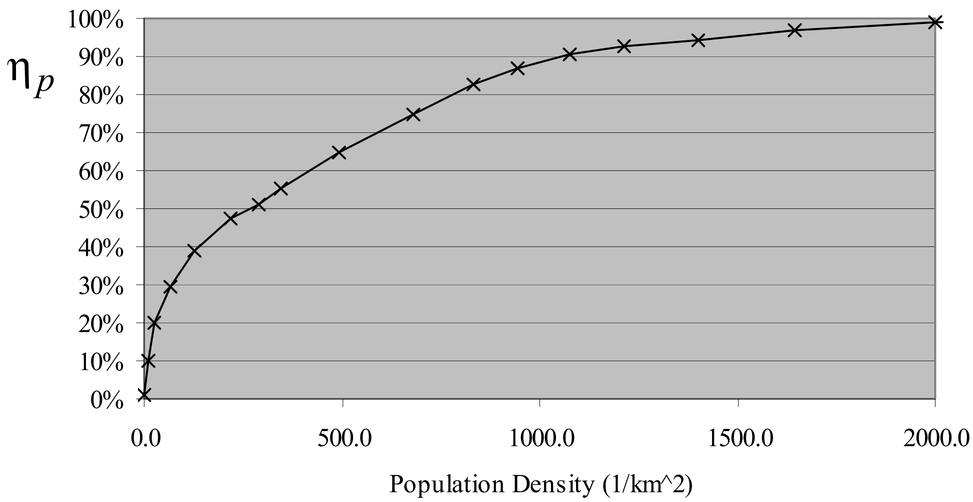


Figure 2: Example penetration factor η_p.

The representation in Figure 2 indicates the relationship to the local environment classifications of Urban, Suburban and Rule areas. Shown in Table 1 is the corresponding mobile penetration if the classifications of Urban (greater than 1070 people per km2), Suburban (greater than 420 people per km2) and Rural (greater than 10 people per km2) are utilized.

Table 1: Penetration and population density to environment classification.

Local Environment	Population Density (per km^2)	Mobile Penetration η_p
Urban	1070	90%
Suburban	420	60%
Rural	10	10%

The total number of base stations is the sum over all sizes of base stations

$$N_{bs} = \sum_{R_h} N(R_h) \tag{7}$$

2.2.2 Transmit power from a deployment area with various sizes of cells

Data provided for the characteristics of base stations specify the maximum power supplied to the antenna of a base station. For the largest cell sizes utilized by the system this accurately represents the peak power, for cells that are smaller in radius the power will be reduced in order to increase the capacity of the system in areas of high utilization. For this analysis it is assumed that the power is reduced as the square of the distance, this is represented as

$$P(R_h) = P(R_{h\max})\left(\frac{R_h}{R_{h\max}}\right)^2 \tag{8}$$

where:

$P(R_h)$ = Transmit power for a cell of radius R_h; and

$R_{h\max}$ = Maximum cell radius under consideration for analysis.

In order to represent this aspect the average peak power transmitted in a deployment area is computed as

$$\widehat{P}_{tij} = \frac{P(R_{h\max})}{N_{bs}} \sum_{R_h} \left(N(R_h) \left(\frac{R_h}{R_{h\max}}\right)^2 \right) \tag{9}$$

where:

$P_{\max} = P(R_{h\max})$ = Maximum transmit power supplied to the antenna input.

Utilization of the average peak transmit power in equation (4), the power received by the satellite can then be computed as

$$P_r = \sum_{i=1}^{m} \frac{G_{ti} G_{ri} \widehat{P}_{tij} N_{bs}}{l_{1i} l_{2i} l_{3i}} \tag{10}$$

Table 2 illustrates an example of computing $\widehat{P}_{tij}$ for a city of population 140,000 located in the US utilizing the parameters found in the above figures for η_p and η_{R_h}.

Table 2: Example of computing $\widehat{P}_{tij}$ for a city of size 140,000.

R_p	6.4 *km*			
Population density	1077/km^2			
	$R_h = 315m$	$R_h = 1km$	$R_h = 10km$	
η_p	91% =	91%	91%	
η_{R_h}	71%	24%	6%	
$N(R_h)$	266	9	1	$N_{bs} = 276$
$\widehat{P}_{tij}$	0.0049 P_{max}			
$\widehat{P}_{tij} N_{bs}$	1.3524 P_{max} Total Power Supplied to Ant.			

2.3 Reference elevation radiation pattern for the base station antenna

The reference radiation pattern for the base station antennas is based on Recommendation ITU-R F.1336 with *k*=0. See Annex C for justification of this pattern. The omnidirectional pattern is obtained by using 3 sectoral antennas, each with gain of 17 dBi and a 120 degree 3 dB beamwidth in the horizontal plane. The reference radiation pattern of the transmitting antenna, ignoring any down-tilt, conformed to the following pattern in the vertical plane.

$$G(\phi) = G_0 - 12\left(\frac{\phi + \phi_{dt}}{\phi_3}\right)^2 \qquad \text{for } |\phi + \phi_{dt}| \le \phi_3 \qquad (11a)$$

$$G(\phi) = G_0 - 12 - 10\log\left(\frac{\phi + \phi_{dt}}{\phi_3}\right) \qquad \text{for } |\phi + \phi_{dt}| > \phi_3 \qquad (11b)$$

where:

$G(\phi)$ = Gain relative to an isotropic antenna (dBi);
G_0 = Maximum gain in the horizontal plane (dBi);
ϕ = Elevation angle measured in the vertical plane (degrees);
ϕ_{dt} = Down tilt of antenna (degrees); and,
ϕ_3 = The 3 dB beamwidth in the vertical plane (degrees).

$$\phi_3 = \frac{31000 \times 10^{-0.1G_0}}{90} \qquad (11c)$$

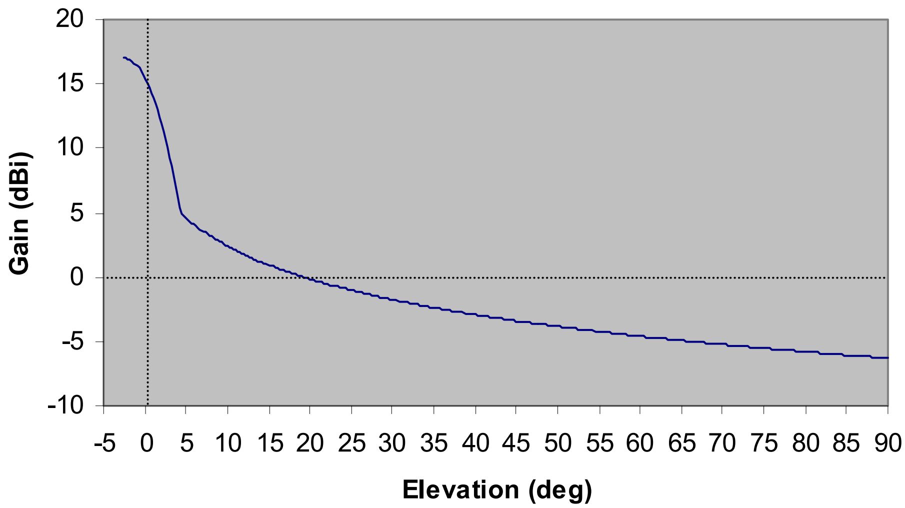


Figure 3: Example elevation radiation pattern for an antenna with $G_0 = 17$ dBi and $\phi_{dt} = 2.5^\circ$.

2.4 Excess loss factor

The factor l_2 accounts for an average loss in excess of free-space due to several stationary and time-dependent atmospheric effects. The supporting technical analysis for the DoD interim report is considered 10 dB as reasonable for this factor that is applied to all elevation angles [vi]. Design of LEO communication systems in the 1610-1626.5 MHz band, in which a significant amount of communications occur at elevation angles less than 20 degrees, typically utilize link margins of 16 dB. Considering that this propagation factors is representative of a population of base stations, the 10 dB loss factor seems appropriate for low elevation angles. For larger elevation angles this factor should go to zero. For this analysis the loss factor utilized is shown in Figure 4.

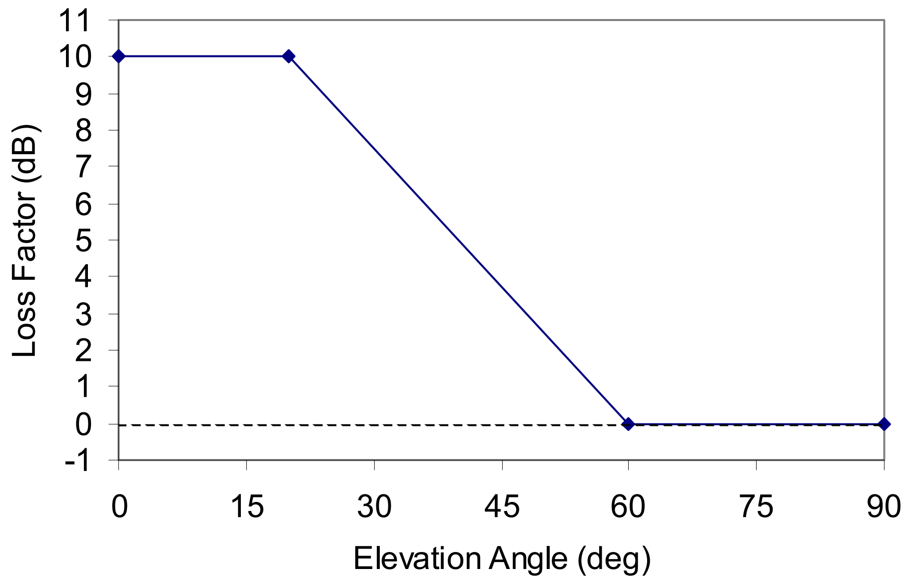


Figure 4: Elevation angle dependence of average loss in excess of free-space due to several stationary and time-dependent atmospheric effects, l_2.

3 Illustrative examples

An input parameter to the methodology is a database of urban population an since the analysis is intend to give an upper bound to the interference for future use of IMT-2000 systems two possible sets of data are considered. In section 3.1 results are presented based upon the population projected for the year 2015. This data set contains only urban populations larger than 750,000, which for this database there are a total of 431 urban locations representing a population of 1.481 billion.

In order to more closely relate to the database of urban population utilized in the DoD interim report a database from the United Nations Demographic Yearbook 1995 is utilized [vii]. This database contains 3,312 major cities or urban agglomerations including capital cities and cities with more than 100,000 population. The worldwide population count for this database is 1.642 billion. Analysis results for this database are contained in section 3.2. For comparison the database utilized in the DoD interim report contained 2763 urban locations [vi] and represented a population of 1.333 billion [viii].

3.1 United Nations population estimates for the year 2015

To illustrate the results obtained by applying the methodology found in section 2 a database of 431 urban population centers with a population estimated by the United Nations to exceed 750,000 people in the year 2015 is utilized [ix]. A portion of this data set is found in Table 8 (Annex A). Parameters required for the simulation are found in Table 3.

The approach utilized to estimate the power radiating from a metropolitan area is based on population density (see §2.2.1). Annex B shows that an upper bound to the power radiating from a metropolitan area can be found. The benefit of utilizing this upper bound is that specific relative deployment factors for each base station size is no longer required, i.e. the factor η_{R_h} can be ignored. This upper bound is found when the following assumptions are utilized:

1) Only base stations with the largest radius cover the metropolitan area; and
2) The number of base stations must be increased by the one minus the total number of different size cells considered in the deployment.

The simulation is performed for altitudes of 250 km, 833 km, 20200 km and 35748 km above the earth for all locations in a 2-degree grid in latitude and longitude. Furthermore, in order to assess the differential impact that operations in the US can have, the simulations are performed with all cities in the database and for all cities minus those located in the US (the database contains 45 cities located in the US with population of 750,000 in the year 2015). The peak power received by a satellite at these altitudes is found in Table 4 along with the peak power that a satellite will receive when communicating with earth stations located in CONUS. The specific received powers are found in Figure 5 through Figure 9. Shown in Annex D is a cross check of the simulations results for an orbital altitude of 35748 km, results indicate that the simulations are within the bounds expected.

Table 3: Parameters utilized in this example.

Parameter	Value	Note
P_{max}	-43 dBW/Hz	Computed from parameters found in [x] for a UWC-136 base station with 200 kHz operating bandwidth. CDMA-2000, W-CDMA and TD-CDMA all have lower transmit power densities.
G_{ri}	-5 dBi	Receive system gain from [x].
l_{2i}	10	From [xi], as modified in §2.4.
l_{3i}	0	Assumes co-polarization between signals.
$G_0 = G_{ti}$	17 dBi	From parameters found in [x] for all systems.
ϕ_{dt}	2.5 degrees	From parameters found in [x] for all systems.

Table 4: Summary of Peak Received Power

Altitude (km)	Peak received power to satellite communicating with earth stations over CONUS (dBW/Hz)	Peak Received Power (dBW/Hz)		
		All Cities	No US	Increase due to US
250	-181.2	-178.7	-179.0	0.3
833	-186.3	-183.9	-184.2	0.3
20200	-201.5	-201.5	-202.1	0.6
35748	-206.0	-206.0	-206.7	0.7

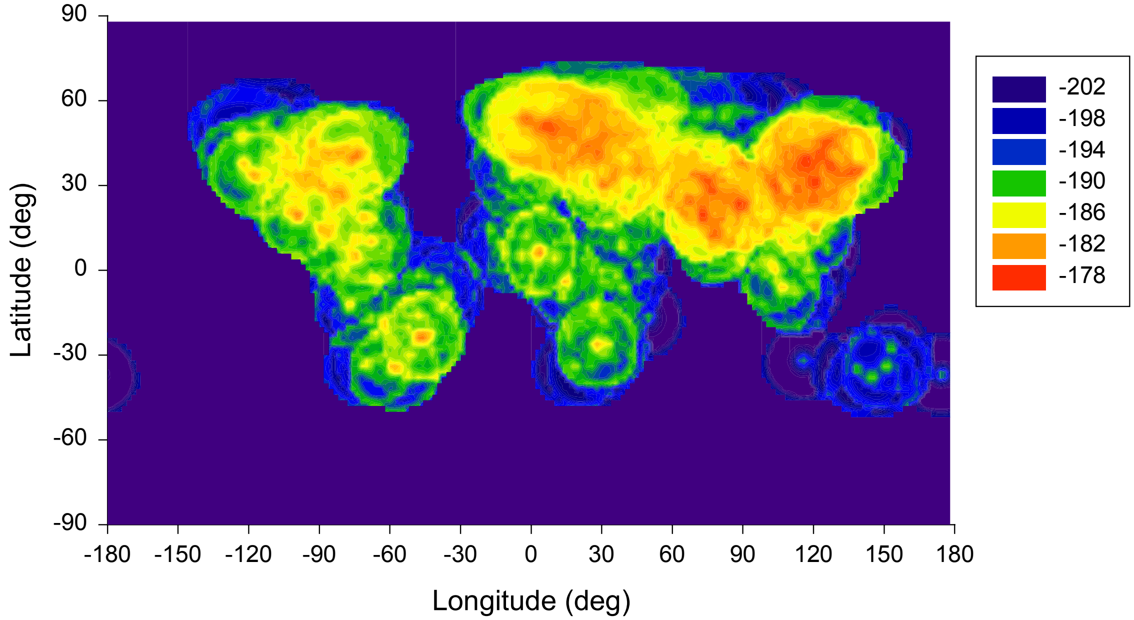


Figure 5: Spectral power (dBW/Hz) received by satellite at an altitude of 250 km (All Cities).

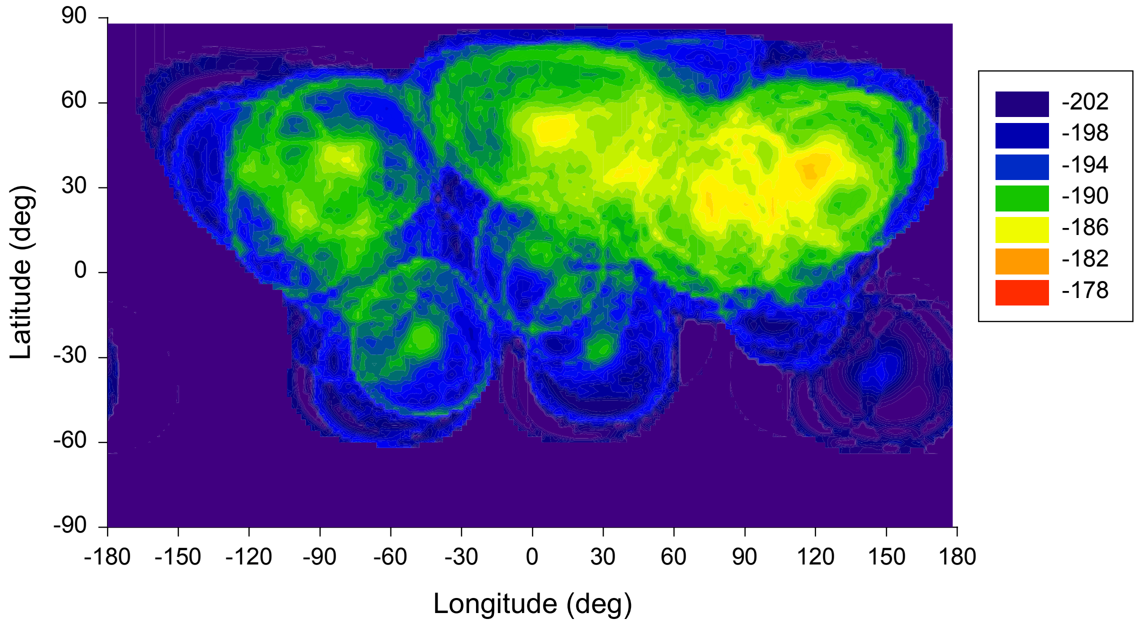


Figure 6: Spectral power (dBW/Hz) received by satellite at an altitude of 833 km (All Cities).

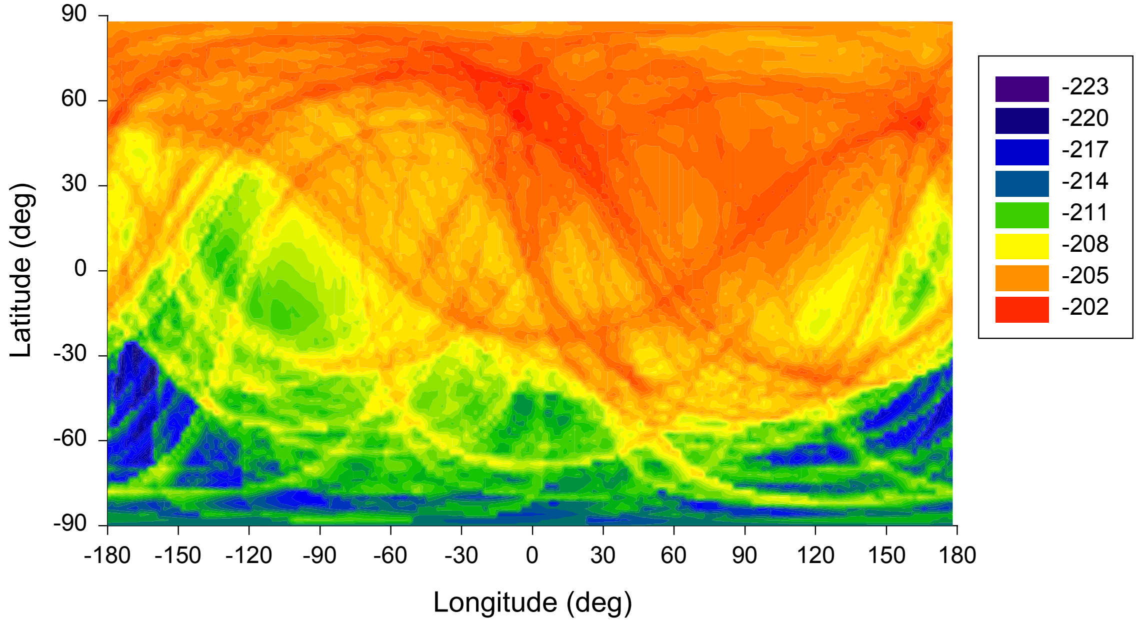


Figure 7: Spectral power (dBW/Hz) received by satellite at an altitude of 20200 km (All Cities).

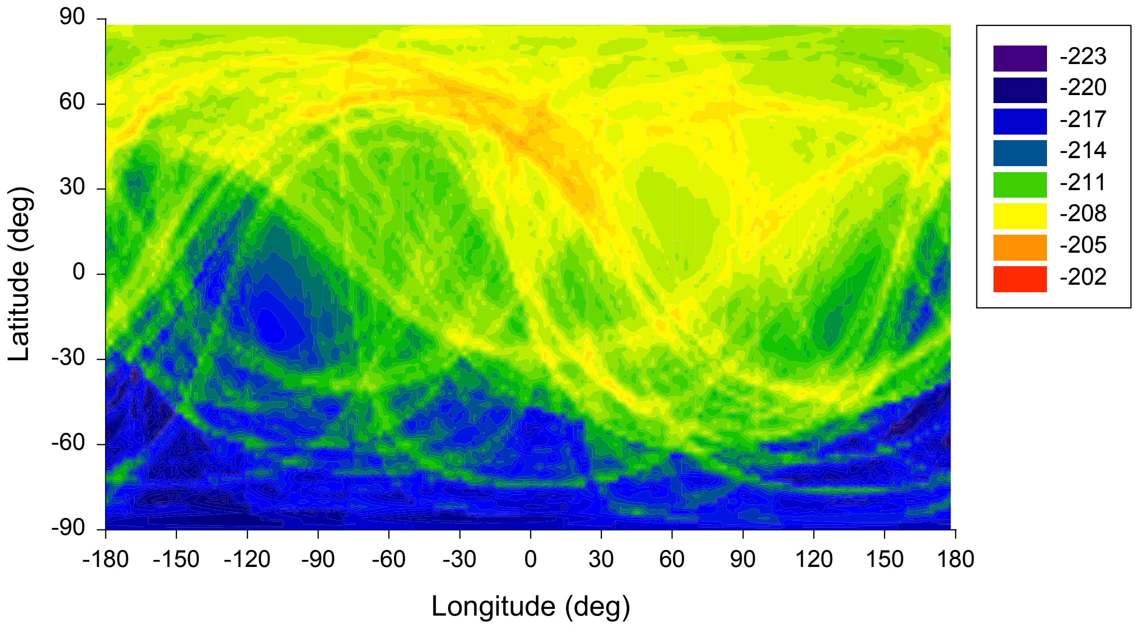


Figure 8: Spectral power (dBW/Hz) received by satellite at an altitude of 35748 km (All Cities).

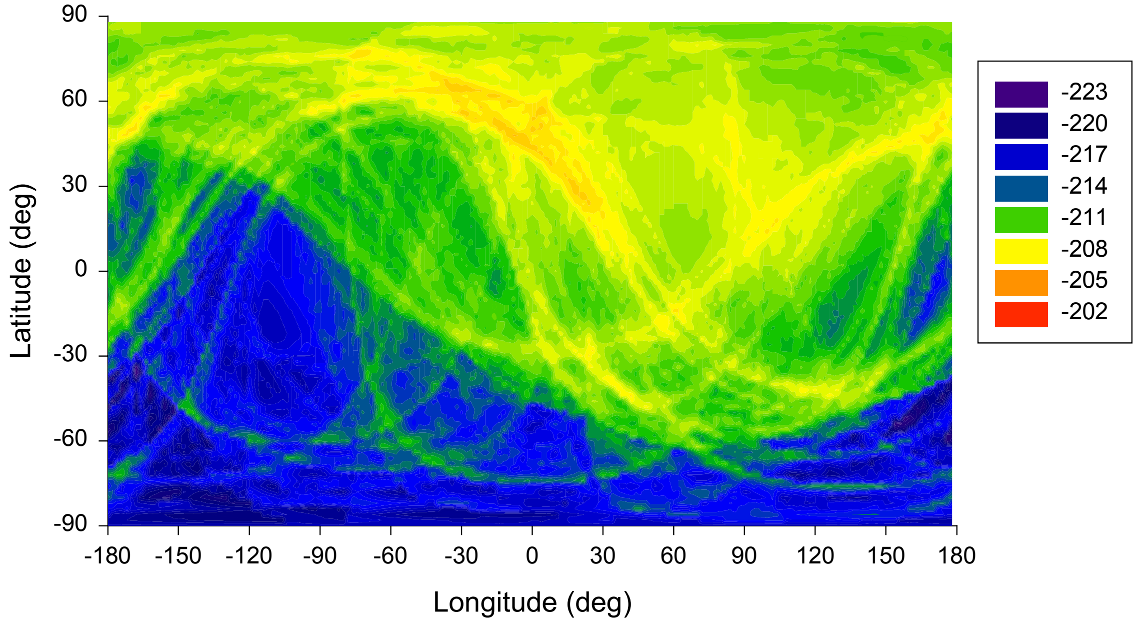


Figure 9: Spectral power (dBW/Hz) received by satellite at an altitude of 35748 km (No US).

3.2 United Nations Demographic Yearbook 1995

Results in this section are obtained by applying the methodology found in section 2 to a database of 3312 urban population centers with a population from the United Nations Demographic Yearbook 1995 [vii]. Parameters required for the simulation are found in Table 3.

The simulation is performed for altitudes of 250 km, 833 km, 20200 km and 35748 km above the earth for all locations in a 2-degree grid in latitude and longitude. Furthermore, in order to assess the differential impact that operations in the US can have, the simulations are performed with all cities in the database and for all cities minus those located in the US (the database contains 209 cities located in the US). The peak power received by a satellite at these altitudes is found in Table 5 along with the peak power that a satellite will receive when communicating with earth stations located in CONUS. The specific received powers are found in through Figure 10 through Figure 14.

Table 5: Summary of peak power received.

Altitude (km)	Peak received power to satellite communicating with earth stations over CONUS (dBW/Hz)	Peak Received Power (dBW/Hz)		
		All Cities	No US	Increase due to US
250	-178.3	-171.2	-171.2	0.0
833	-182.3	-178.2	-178.2	0.0
20200	-197.0	-196.9	-197.0	0.1
35748	-200.8	-200.8	-200.9	0.1

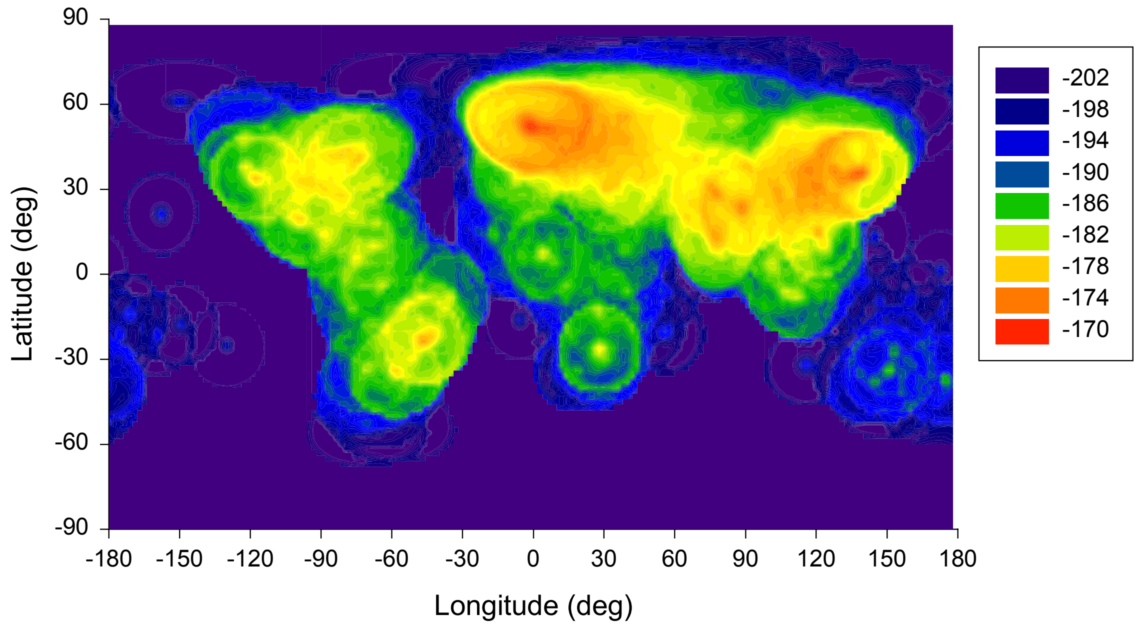


Figure 10: Spectral power (dBW/Hz) received by satellite at an altitude of 250 km (All Cities).

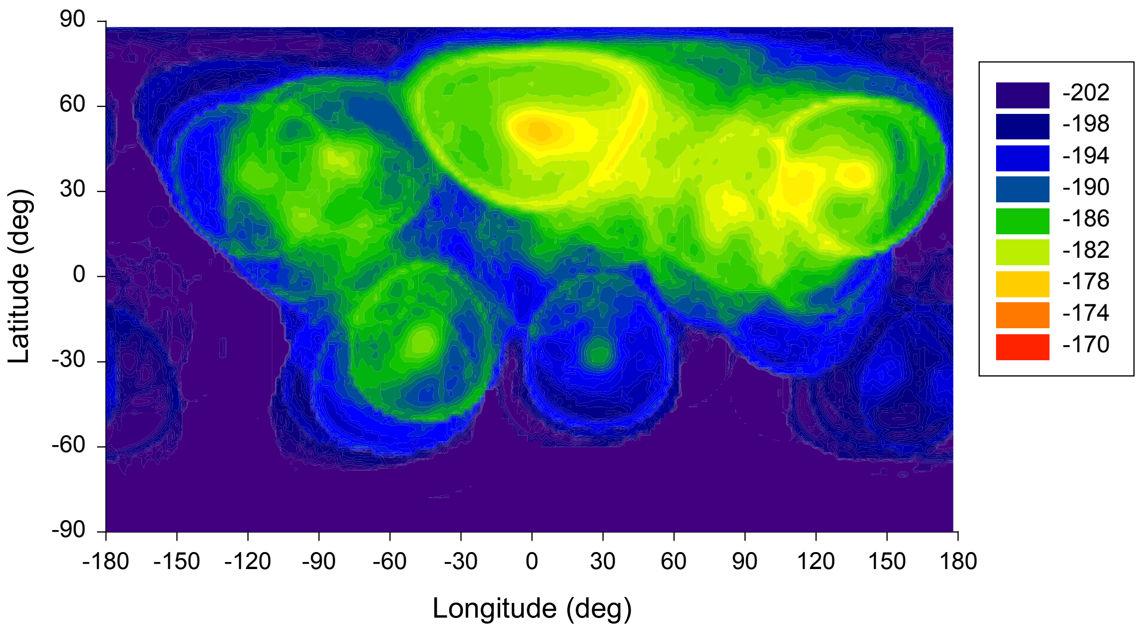


Figure 11: Spectral power (dBW/Hz) received by satellite at an altitude of 833 km (All Cities).

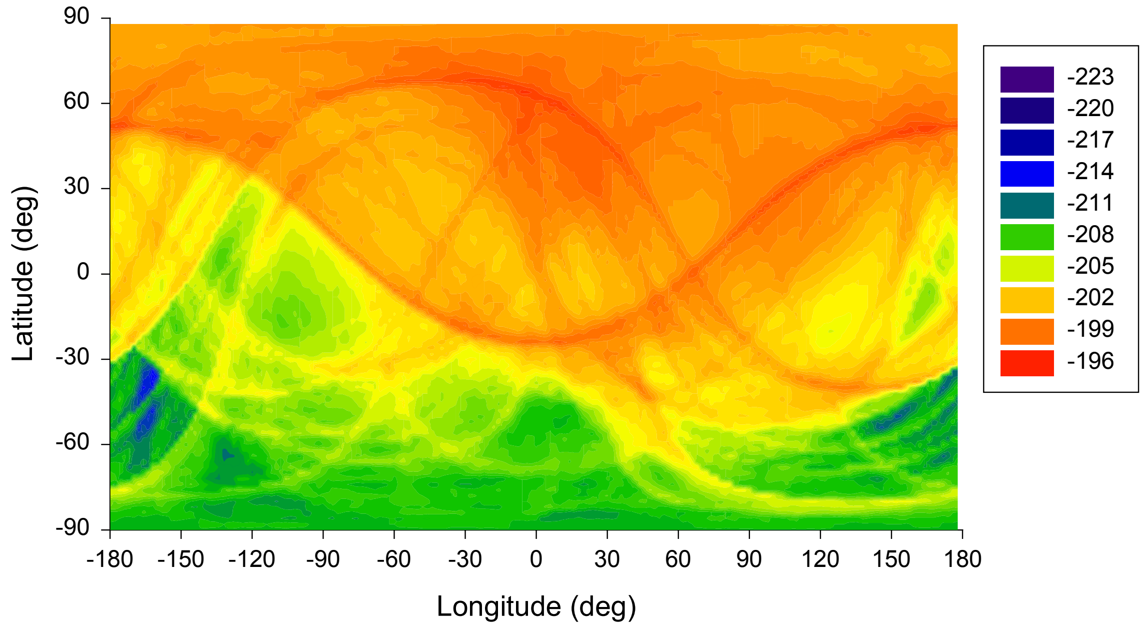


Figure 12: Spectral power (dBW/Hz) received by satellite at an altitude of 20200 km (All Cities).

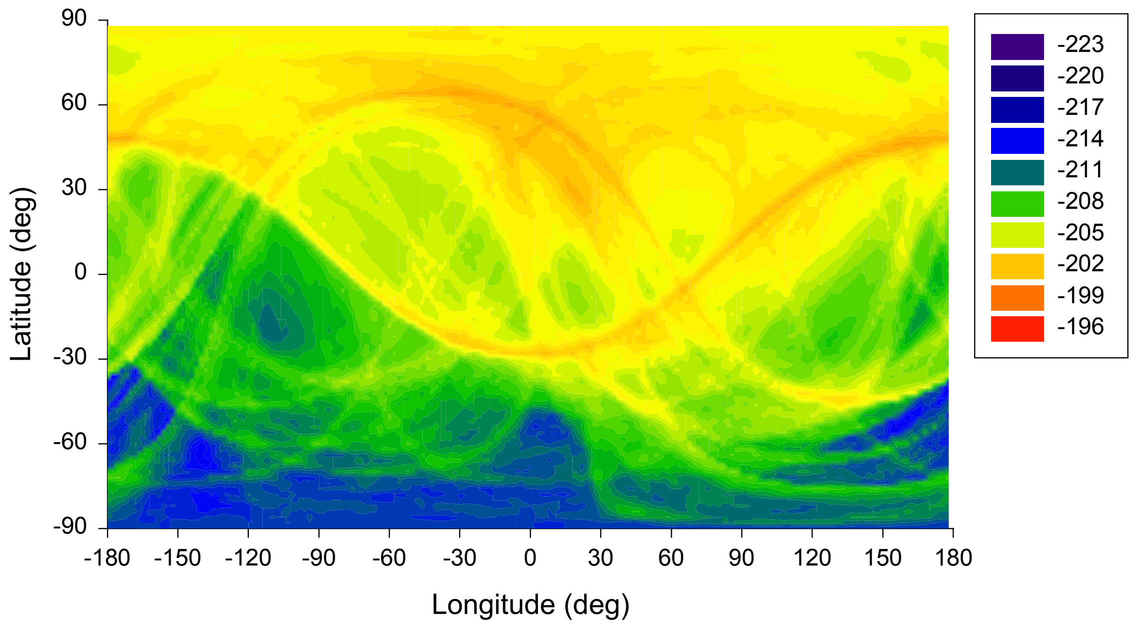


Figure 13: Spectral power (dBW/Hz) received by satellite at an altitude of 35748 km (All Cities).

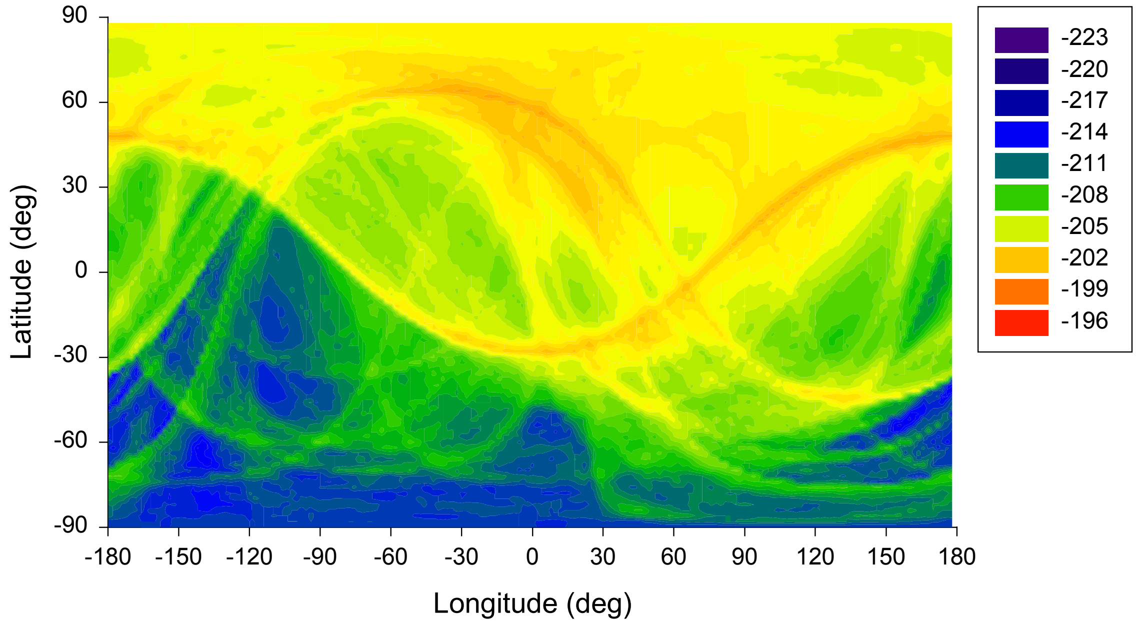


Figure 14: Spectral power (dBW/Hz) received by satellite at an altitude of 35748 km (No US).

ANNEX A

Table 6: A comparison between actual and calculated area for twenty of the most populous U.S. urban population centers: based on 1990 population data; $\alpha = 0.0355$; $\beta = 0.44$

Urban population center	**Pop (1000)**	**Area (mi^2)**	**Area (km^2)**	**Calc area (km^2)**	**Relative Error (%)**
Atlanta	2157	1137	2943.6	1484	-49.6%
Baltimore	1890	593	1535.2	1321	-14.0%
Boston	2775	891	2306.7	1852	-19.7%
Buffalo	954	286	740.4	724	-2.2%
Chicago	6792	1585	4103.4	4072	-0.8%
Cincinnati	1212	512	1325.5	893	-32.6%
Cleveland	1677	636	1646.5	1189	-27.8%
Dallas-Ft Worth	3198	1443	3735.8	2098	-43.8%
Denver	1518	459	1188.3	1089	-8.3%
Detroit	3697	1119	2897.0	2384	-17.7%
Fort Lauderdale	1238	327	846.6	910	7.5%
Houston	2902	1177	3047.1	1927	-36.8%
Kansas City	1275	762	1972.7	934	-52.6%
Los Angeles	11402	1966	5089.7	6423	26.2%
Miami	1915	353	913.9	1336	46.2%
Milwaukee	1226	512	1325.5	903	-31.9%
Minneapolis-St Paul	2080	1063	2752.0	1437	-47.8%
New Orleans	1040	270	699.0	781	11.7%
New York	16044	2967	7681.2	8675	12.9%
Norfolk	1323	664	1719.0	965	-43.9%
Philadelphia	4222	1164	3013.5	2680	-11.1%
Phoenix	2006	741	1918.4	1392	-27.4%
Pittsburgh	1678	778	2014.1	1190	-40.9%
Portland	1172	388	1004.5	867	-13.6%
Riverside-San Bernadino	1170	460	1190.9	866	-27.3%
Sacramento	1097	334	864.7	818	-5.3%
San Antonio	1129	438	1133.9	839	-26.0%
San Diego	2348	690	1786.3	1599	-10.5%
San Francisco-Oakland	3630	874	2262.7	2346	3.7%
San Jose	1435	338	875.0	1037	18.5%
Seattle	1744	588	1522.3	1231	-19.2%
St. Louis	1947	728	1884.7	1356	-28.1%
Tampa-St. Petersburg	1709	650	1682.8	1209	-28.2%
Washington, DC	3363	945	2446.5	2193	-10.3%

Table 7: A comparison between actual and calculated area for eighty-five of the most populous urban population centers: based on 1985 population data; $\alpha = 0.015$; $\beta = 0.44$.

Rank	Urban population center	Pop (1000)	Area (mi^2)	Pop/mi^2	Area (km^2)	Calc area (km^2)	Relative Error
1	Tokyo-Yokohama	25,434	1,089	23,355	2788	2,323	-16.7%
2	Mexico City	16,901	522	32,377	1336	1,621	21.3%
3	Sao Paulo	14,911	451	33,062	1155	1,452	25.8%
4	New York	14,598	1,274	11,458	3261	1,425	-56.3%
5	Seoul	13,665	342	39,956	876	1,345	53.6%
6	Osaka-Kobe-Kyoto	13,562	495	27,398	1267	1,336	5.4%
7	Buenos Aires	10,750	535	20,093	1370	1,089	-20.5%
8	Calcutta	10,462	209	50,057	535	1,063	98.7%
9	Bombay	10,137	95	106,705	243	1,034	325.2%
10	Rio de Janeiro	10,116	260	38,908	666	1,032	55.1%
11	Moscow	9,873	379	26,050	970	1,010	4.1%
12	Los Angeles	9,636	1,110	8,681	2842	989	-65.2%
13	London	9,442	874	10,803	2237	971	-56.6%
14	Paris	8,633	432	19,984	1106	898	-18.8%
15	Cairo	8,595	104	82,644	266	894	235.9%
16	Manila	8,485	188	45,133	481	884	83.7%
17	Jakarta	8,122	76	106,868	195	851	337.3%
18	Essen	7,604	704	10,801	1802	803	-55.5%
19	Teheran	7,354	112	65,661	287	780	171.9%
20	Delhi	6,993	138	50,674	353	746	111.1%
21	Shanghai	6,698	78	85,872	200	718	259.6%
22	Chicago	6,511	762	8,545	1951	700	-64.1%
23	Karachi	6,351	190	33,426	486	685	40.9%
24	Lagos	6,054	56	108,107	143	657	358.2%
25	Beijing	5,608	151	37,139	387	614	58.9%
26	Taipei	5,550	138	40,217	353	609	72.3%
27	Lima	5,447	120	45,392	307	599	94.9%
28	Hong Kong	5,415	20	270,750	51	596	1063.1%
29	Istanbul	5,389	165	32,661	422	593	40.4%
30	Bangkok	4,998	102	49,000	261	555	112.5%
31	Madras	4,983	115	43,330	294	554	88.0%
32	Bogota	4,711	79	59,633	202	527	160.5%
33	Santiago	4,700	128	36,719	328	526	60.4%
34	Milan	4,635	344	13,474	881	519	-41.0%
35	Tianjin	4,622	49	94,327	125	518	313.0%
36	Leningrad	4,569	139	32,871	356	513	44.1%
37	Nagoya	4,452	307	14,502	786	501	-36.2%
38	Manchester	4,151	357	11,627	914	471	-48.4%
39	Madrid	4,137	66	62,682	169	470	178.1%
40	Shenyang	4,086	39	104,769	100	465	365.6%
41	Philadelphia	4,025	471	8,546	1206	459	-62.0%
42	Pusan	3,996	54	74,000	138	456	229.7%

Rank	Urban population center	Pop (1000)	Area (mi^2)	Pop/mi^2	Area (km^2)	Calc area (km^2)	Relative Error
43	Barcelona	3,842	87	44,161	223	440	97.7%
44	San Francisco	3,790	428	8,855	1096	435	-60.3%
45	Bangalore	3,685	50	73,700	128	424	231.6%
46	Lahore	3,603	57	63,211	146	416	185.2%
47	Sydney	3,396	338	10,047	865	395	-54.4%
48	Baghdad	3,371	97	34,753	248	392	58.0%
49	Dhaka	3,283	32	102,594	82	383	368.0%
50	Athens	3,252	116	28,034	297	380	28.0%
51	Ho Chi Mihn City	3,250	31	104,839	79	380	378.8%
52	Gaungzhou	3,248	79	41,114	202	380	87.8%
53	Detroit	3,133	468	6,694	1198	368	-69.3%
54	Miami	3,123	448	6,971	1147	367	-68.0%
55	Belo Horinzonte	3,059	79	38,722	202	360	78.1%
56	Wuhan	3,048	65	46,892	166	359	115.8%
57	Ahmenabad	3,037	32	94,906	82	358	337.0%
58	Berlin	3,033	274	11,069	701	358	-49.0%
59	Hyderabad	3,022	88	34,341	225	356	58.2%
60	Caracas	2,993	54	55,426	138	353	155.7%
61	Toronto	2,972	154	19,299	394	351	-10.9%
62	Surabaya	2,962	43	68,884	110	350	218.1%
63	Rome	2,944	69	42,667	177	348	97.2%
64	Naples	2,862	62	46,161	159	340	114.1%
65	Melbourne	2,852	327	8,722	837	339	-59.5%
66	Montreal	2,827	164	17,238	420	336	-19.9%
67	Kinshasa	2,794	57	49,018	146	333	128.0%
68	Guadalajara	2,746	78	35,205	200	328	64.1%
69	Alexandria	2,660	35	76,000	90	319	255.6%
70	Yangon	2,558	47	54,426	120	308	155.8%
71	Singapore	2,556	78	32,769	200	308	54.0%
72	Porte Allegre	2,536	231	10,978	591	305	-48.3%
73	Harbin	2,518	30	83,933	77	304	295.3%
74	Casablanca	2,495	35	71,286	90	301	236.1%
75	Kiev	2,489	62	40,145	159	300	89.3%
76	Dallas	2,486	419	5,933	1073	300	-72.0%
77	Boston	2,470	303	8,152	776	298	-61.5%
78	Washington	2,456	357	6,880	914	297	-67.5%
79	Monterey	2,351	77	30,532	197	286	45.0%
80	Ankara	2,338	55	42,509	141	284	102.0%
81	Budapest	2,297	138	16,645	353	280	-20.7%
82	Chengdu	2,250	25	90,000	64	275	329.6%
83	Birmingham	2,211	223	9,915	571	271	-52.6%
84	Houston	2,104	310	6,787	794	259	-67.3%
85	Bucharest	2,095	52	40,288	133	258	94.0%

Table 8: Estimate of 93 highest populated cities in the year 2015.

Lat	Lon	2015 pop	Location
35.667	139.75	28887	Japan Tokyo
18.977	72.85	26218	India Bombay
6.45	3.467	24640	Nigeria Lagos
-23.55	-46.633	20320	Brazil Sao Paulo
23.7	90.367	19486	Bangladesh Dhaka
24.85	67.033	19377	Pakistan Karachi
19.417	-99.167	19180	Mexico Mexico City
31.25	121.5	17969	China Shanghai
40.75	-74	17602	United States New York
22.5	88.333	17305	India Calcutta
28.667	77.233	16860	India Delhi
39.917	116.433	15572	China Beijing
14.617	120.967	14657	Philippines Metro Manila
30.05	31.25	14418	Egypt Cairo
34	-118.167	14217	United States Los Angeles
-6.133	106.75	13923	Indonesia Jakarta
-34.667	-58.5	13856	Argentina Buenos Aires
39.133	117.2	13530	China Tianjin
37.5	127	12980	Rep. of Korea Seoul
41.033	28.95	12328	Turkey Istanbul
-22.883	-43.283	11860	Brazil Rio de Janeiro
30.3	120.117	11407	China Hangzhou
34.4	135.27	10609	Japan Osaka
17.367	78.433	10489	India Hyderabad
35.667	51.433	10309	Iran, Isl.Rep.ofTeheran
31.567	74.367	10047	Pakistan Lahore
13.733	100.5	9844	Thailand Bangkok
48.867	2.333	9694	France Paris
-4.356	15.3	9430	Zaire Kinshasa
-12.1	-77.05	9388	Peru Lima
55.75	37.7	9299	Russian Fed. Moscow
13.083	80.278	9173	India Madras
43.833	125.517	8931	China Changchun
4.633	-74.083	8394	Colombia Bogota
45.833	126.666	8111	China Harbin
12.967	77.583	8005	India Bangalore
36.683	117	7900	China Jinan
30.617	104.001	7840	China Chengdu
41.833	123.433	7715	China Shenyang
51.5	-0.167	7640	United Kingdom London
41.833	-87.75	7458	United States Chicago
36.067	120.317	7292	China Qingdao
23.133	113.333	7234	China Guangzhou
33.333	44.433	6866	Iraq Baghdad
16.46	96.09	6775	Myanmar Yangon
51.467	6.983	6596	Germany Essen
9.05	38.7	6578	Ethiopia Addis Ababa
30.583	114.317	6509	China Wuhan
36.583	114.483	6393	China Handan
36.75	3	6352	Algeria Algiers
22.245	114.217	6325	Hong Kong Hong Kong
-33.5	-70.667	6066	Chile Santiago
23	72.667	5842	India Ahmedabad
31.217	29.917	5441	Egypt Alexandria
30.633	103.667	5369	China Chongqing
-25.939	32.555	5306	Mozambique Maputo
5.317	-4.017	5259	Côte d'Ivoire Abidjan
24.65	46.767	5230	Saudi Arabia Riyadh
43.7	-79.417	5220	Canada Toronto
34.5	69.167	5201	Afghanistan Kabul
18.567	73.967	5143	India Pune (Poona)
59.917	30.417	5132	Russian Fed. St. Petersburg
0.539	103.25	5089	Indonesia Bandung
-2.617	-67.5	5001	Brazil Belo Horizonte
-8.833	13.25	4969	Angola Luanda
22.333	91.8	4857	Bangladesh Chittagong
6.25	-75.6	4835	Colombia Medell¦n
33.594	-7.583	4835	Morocco Casablanca
10.767	106.717	4797	Viet Nam Ho Chi Minh
40	-75.167	4780	United States Philadelphia
32.04	118.46	4728	China Nanjing
38.883	121.617	4704	China Dalian
15.55	32.533	4667	Sudan Khartoum
18.5	-69.95	4663	Dominican Rep. Santo Domingo
34.267	108.9	4661	China Xian
32.683	51.683	4641	Iran, Isl.Rep.ofEsfahan
35.083	129.033	4523	Rep. of Korea Pusan
-30.05	-51.167	4467	Brazil Porto Alegre
14.633	-90.367	4467	Guatemala Guatemala City
37.75	-122.45	4461	United States San Francisco
20.667	-103.333	4457	Mexico Guadalajara
32.833	-96.833	4380	United States Dallas
-33.933	18.467	4371	South Africa Cape Town
38.867	-77	4361	United States Washington, D.C.
45.467	9.2	4251	Italy Milan
-1.283	36.833	4228	Kenya Nairobi
42.333	-83.083	4113	United States Detroit
40.26	-3.42	4072	Spain Madrid
39.917	32.833	4028	Turkey Ankara
1.283	103.85	4009	Singapore Singapore
-33.917	151.167	3990	Australia Sydney
26.833	80.9	3959	India Lucknow

ANNEX B
Upper Bound to Power Radiated from Urban Area

The total power radiating from a metropolitan area is computed as the summation of the transmit power of all base stations located in this area, this is represented as:

$$P_{ti} = \sum_{j=1}^{N_{bs}} P_{tij} = \sum_{R_h} N(R_h) P(R_h) \tag{B-1}$$

where:

$N(R_h)$ = Number of base stations with radius R_h; and

$P(R_h)$ = Transmit power for base station with cell radius of R_h.

The goal of this annex is to arrive an upper bound to the power radiated from a metropolitan area when applying a population-based approach in computing this power as found in §2.2.1. The benefit of utilizing this upper bound is that specific relative deployment factors for each base station size is no longer required, i.e. the factor η_{R_h} can be ignored. It is shown below that this upper limit is found when the following assumptions are utilized:

3) Only base stations with the largest radius cover the metropolitan area;
4) The number of base stations must be increased by the one minus the total number of different size cells considered in the deployment.

To show this the following inequality must hold

$$\left(N'(R_{h\max}) - 1 + \sum_{R_h} 1 \right) P(R_{h\max}) \geq \sum_{R_h} N(R_h) P(R_h) \tag{B-2}$$

where

$N'(R_{h\max})$ = Number of base stations required to cover metropolitan area under the condition that only base stations of size $R_{h\max}$ are utilized.

In equation (B-2) the values $N(R_h)$ and $P(R_h)$ are computed as found in §2.2.1 above. Upon making the substitution of the above equation (8), equation (B-2) now is

$$\left(N'(R_{h\max}) - 1 + \sum_{R_h} 1 \right) P(R_{h\max}) \geq \sum_{R_h} N(R_h) P(R_{h\max}) \left(\frac{R_h}{R_{h\max}} \right)^2 . \tag{B-3}$$

The inequality now becomes

$$N'(R_{h\max}) - 1 + \sum_{R_h} 1 \geq \sum_{R_h} N(R_h) \left(\frac{R_h}{R_{h\max}} \right)^2 . \tag{B-4}$$

Which becomes (via equation (6))

$$Int\left(\eta_p\left(\frac{R_p}{R_{h\max}}\right)^2+T_{R_{h\max}}\right)-1+\sum_{R_h}1\geq\sum_{R_h}Int\left(\eta_{R_h}\eta_p\left(\frac{R_p}{R_h}\right)^2+T_{R_h}\right)\left(\frac{R_h}{R_{h\max}}\right)^2. \quad \text{(B-5)}$$

Since $\left(\frac{R_h}{R_{h\max}}\right)^2\leq 1$ the inequality in (B-5) holds if the following inequality holds

$$\eta_p\left(\frac{R_p}{R_{h\max}}\right)^2+T_{R_{h\max}}-1+\sum_{R_h}1\geq\sum_{R_h}\left(\eta_{R_h}\eta_p\left(\frac{R_p}{R_h}\right)^2+T_{R_h}\right)\left(\frac{R_h}{R_{h\max}}\right)^2. \quad \text{(B-6)}$$

After some rearrangement of the terms on the right side of this inequality we find that (B-6) becomes

$$\eta_p\left(\frac{R_p}{R_{h\max}}\right)^2+T_{R_{h\max}}-1+\sum_{R_h}1\geq\eta_p\left(\frac{R_p}{R_{h\max}}\right)^2\sum_{R_h}\eta_{R_h}+\sum_{R_h}T_{R_h}\left(\frac{R_h}{R_{h\max}}\right)^2. \quad \text{(B-7)}$$

Which becomes

$$T_{R_{h\max}}-1+\sum_{R_h}1\geq\sum_{R_h}T_{R_h}\left(\frac{R_h}{R_{h\max}}\right)^2. \quad \text{(B-8)}$$

Since $T_{R_h}<1$ and $\left(\frac{R_h}{R_{h\max}}\right)^2\leq 1$ the inequities above are true.

In order to illustrate the extent of this upper bound the example utilized in §2.2.2 is shown in Table 9 utilizing the transmit power for a UWC-136 carrier. This example demonstrates that this upper bound over estimates the power radiating from a metropolitan area by 3.5 dB.

Table 9: Illustration of upper bound to the total transmit power

City Population	R_p (km)	Pop. Density (1/km^2)	η_p	Pmax (dBW/Hz)
140,000	6.4	1077.1	0.905	-43
Total power from metro area via approach in section 2.2.2				
R_h	η_{R_h}	T_{R_h}	$N(R_h)$	
0.315	0.706	0.5	266	
1	0.236	0.5	9	
10	0.058	0.9994	1	
$\hat{P}_{tij}$	0.00491	$P_{\max}$		
N_{bs}	276			
Total Power	-41.7	dBW/Hz		
Total power from metro area via upper bound in Annex B				
$R_{h\max}$	$\eta_{R_h \max}$	$T_{R_{h\max}}$	$N'(R_{h\max})$	$N'(R_{h\max}) - 1 + \sum_{R_h} 1$
10	1	0.9994	1	3
$\hat{P}_{tij}$	1.00000	$P_{\max}$		
N_{bs}	3			
Total Power	-38.2	dBW/Hz		
Over estimate	**3.5**	**dB**		

ANNEX C
Base Station Antenna Patterns

One of the discussion points for simulating interference into the TT&C uplinks in the 1.7 GHz band is the appropriate antenna pattern to be utilized in representing the vertical discrimination of base station emissions.

Proposed as a possible antenna mask is reference radiation pattern for the hub station antennas based on Recommendation ITU-R F.1336 with *k*=0. The omnidirectional pattern is obtained by using 3 sectoral antennas, each with gain of 17 dBi and a 120 degree 3 dB beamwidth in the horizontal plane. The reference radiation pattern of the transmitting antenna conforms to the following pattern in the vertical plane.

$$G(\phi) = G_0 - 12\left(\frac{\phi + \phi_{dt}}{\phi_3}\right)^2 \qquad \text{for } |\phi + \phi_{dt}| \le \phi_3 \qquad \text{(C-1a)}$$

$$G(\phi) = G_0 - 12 - 10\log\left(\frac{\phi + \phi_{dt}}{\phi_3}\right) \qquad \text{for } |\phi + \phi_{dt}| > \phi_3 \qquad \text{(C-1b)}$$

where:

$G(\phi)$: gain relative to an isotropic antenna (dBi);

G_0 : the maximum gain in the horizontal plane (dBi);

ϕ : elevation angle measured in the vertical plane (degrees);

ϕ_{dt} : downtilt of antenna (degrees); and,

ϕ_3 : the 3 dB beamwidth in the vertical plane (degrees).

$$\phi_3 = \frac{31000 \times 10^{-0.1 G_0}}{90} \qquad \text{(C-1c)}$$

Shown in Figure 15 through Figure 18 are comparisons of measured antenna data with the proposed mask with the parameters of $G_0 = 17$ dBi and $\phi_{dt} = 2.5^\circ$. Table 10 gives the general characteristics of the antennas considered.

Table 10: General Characteristics of Antenna Products.

Manufacturer	Model	Frequency	Gain
Decibel Products	DB980H90-KL	1710-1880 MHz	17.1 dBi
Decibel Products	DB978H120-KL	1710-1880 MHz	15.1 dBi
DAPA	19300	1710-1990 MHz	17.6 dBi
DAPA	58000XL	1710-1990 MHz	17.1 dBi

The measurement data supports that the proposed mask reasonably represents base station antenna product currently being manufactured.

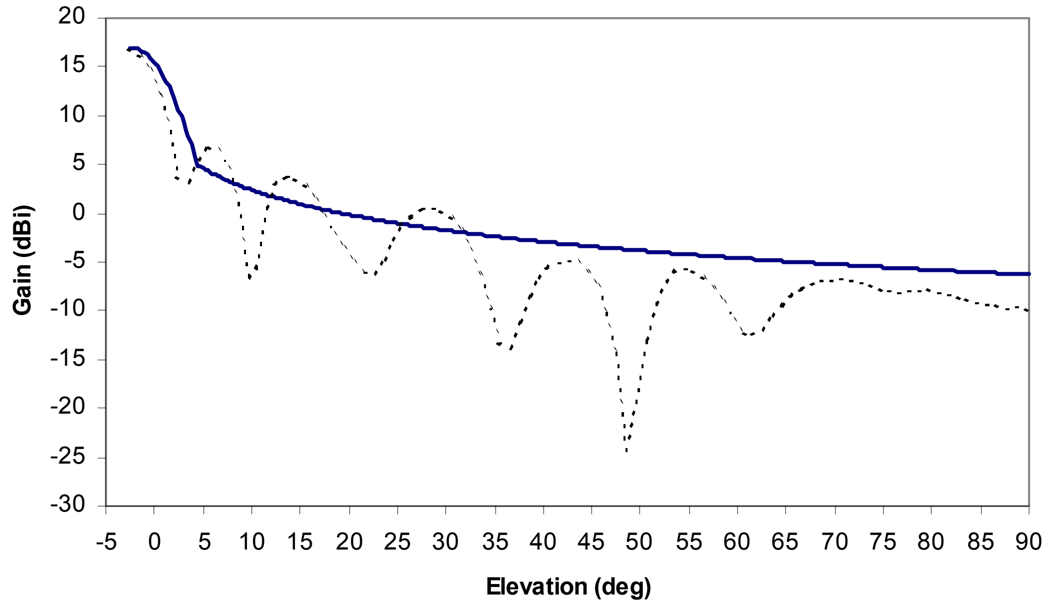


Figure 15: Comparison of Mask with Measured Pattern for Decibel Products antenna DB980H90.

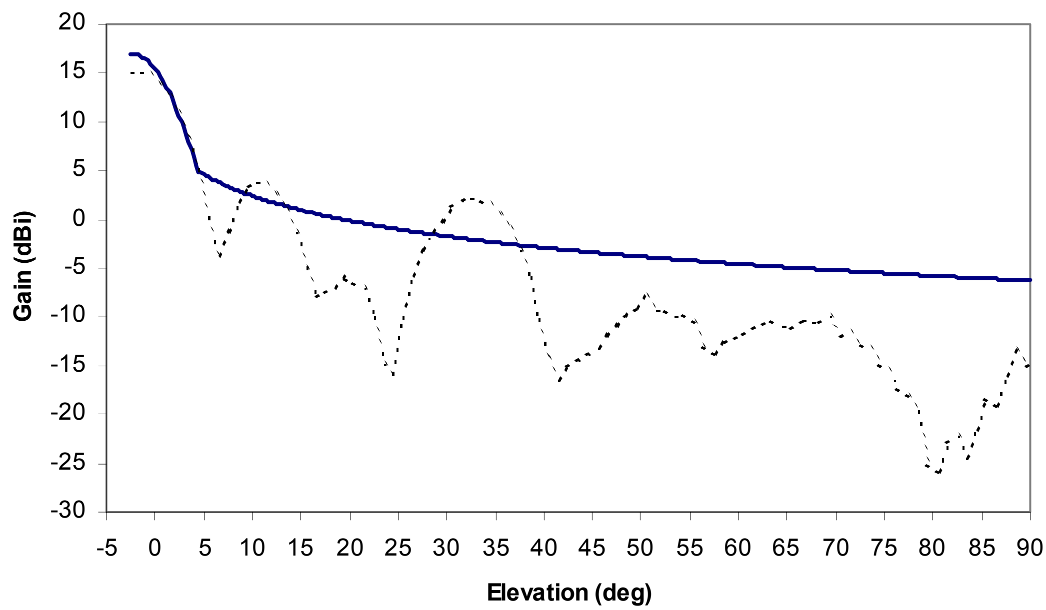


Figure 16: Comparison of Mask with Measured Pattern for Decibel Products antenna DB978H120.

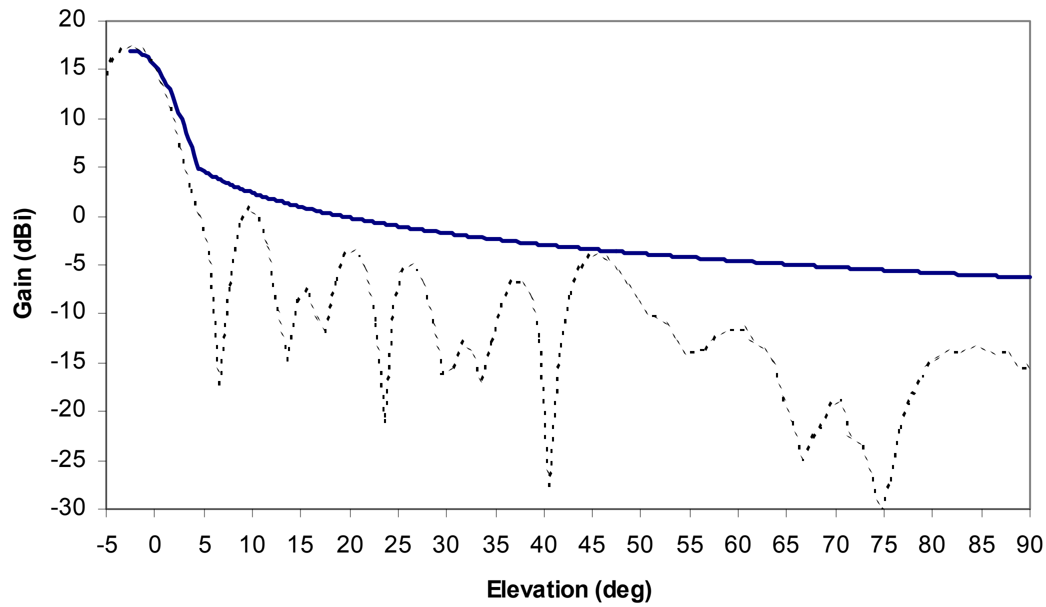


Figure 17: Comparison of Mask with Measured Pattern for DAPA antenna 19000.

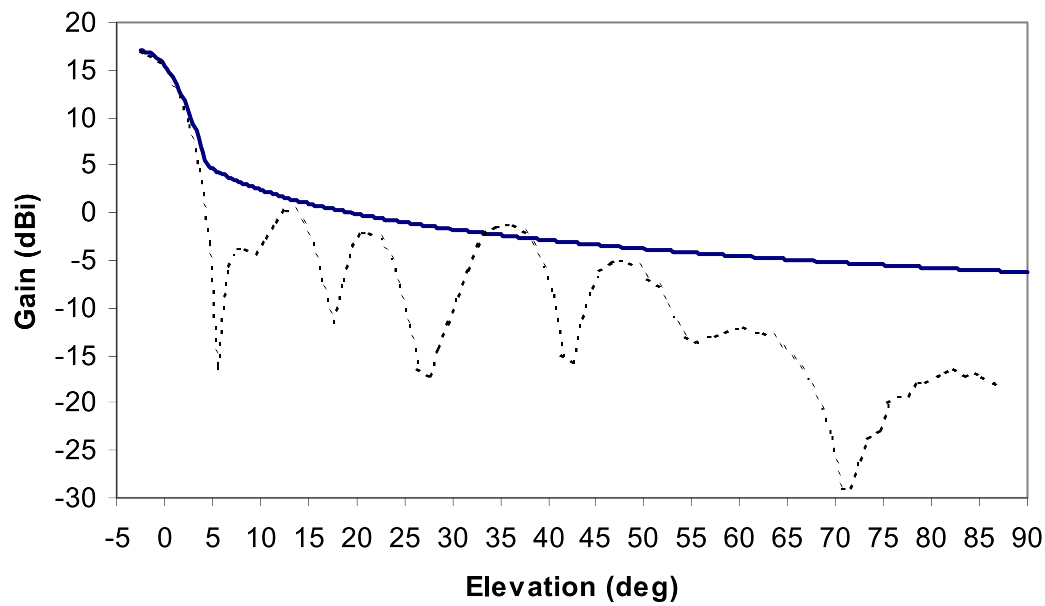
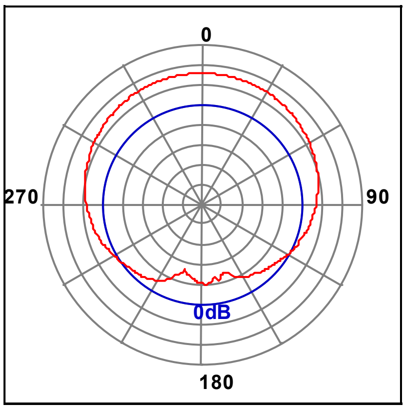


Figure 18: Comparison of Mask with Measured Pattern for DAPA antenna 58000XL.

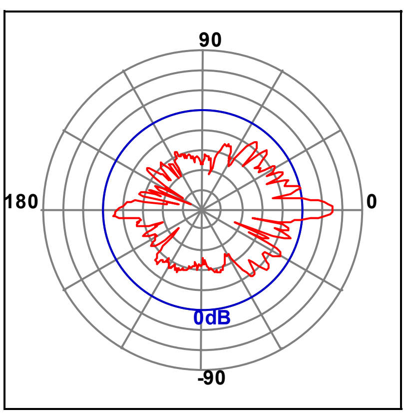
DAPA ***http://www.dapacom.com***

Model 19000 / 19010 113°, 15.5 dBd Panel

Antenna Picture



H-plane



E-plane

GENERAL CHARACTERISTICS	
Frequency Range	1710-1990 MHz
Impedance	50 Ohms
VSWR	<1.4:1
Polarization	Vertical
Rated Power	500 W

ELECTRICAL CHARACTERISTICS		
Beamwidth:	H-plane	113° ±4°(at -3dB)
	E-plane	5.5° ±1°(at -3dB)
Maximum/Minimum Gain		15.5dBd/14.5 dBd
Electrical Downtilt		0°(available -1° to -15°)
Side Lobes		<-15 dB
Front-to-Back Ratio		<-24 dB

MECHANICAL CHARACTERISTICS	
Height x Width x Depth	70.3"x6.3"x2.7" (1785x159x68mm)
Weight	14.6 lbs (6.6kg)
Wind Survival Rating	125 mph (200 km/h)
Wind Load (at 100 mph)	510 N (frontal F1) 217 N (lateral F2)
Flat Plate Equivalent Area	3.05 ft^2 (0.28 m^2)
Connector Types (Female)	Type N, or 7/16 DIN
Materials: Antenna/Radome	Aluminum/ABS

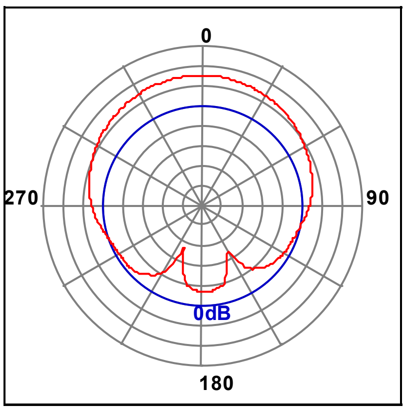
DAPA. Allegany, NY USA. Tel 1 800 325 3272. Int / l Tel +1 716 373 7228. Int / l Fax +1 716 373 5758

DAPA *http://www.dapacom.com*

Model 58000 / 58010 92°, 15 dBd Panel

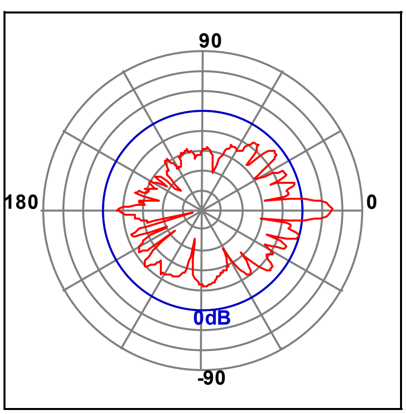
GENERAL CHARACTERISTICS	
Frequency Range	1710-1990 MHz
Impedance	50 Ohms
VSWR	<1.4:1
Polarization	Vertical
Rated Power	500 W

ELECTRICAL CHARACTERISTICS		
Beamwidth:	H-plane	92° ±3°(at -3dB)
	E-plane	7° ±1°(at -3dB)
Maximum/Minimum Gain		15dBd/14 dBd
Electrical Downtilt		0°(available -1° to -15°)
Side Lobes		<-15 dB
Front-to-Back Ratio		<-25 dB



H-plane

MECHANICAL CHARACTERISTICS	
Height x Width x Depth	53.3"x6.3"x2.7" (1353x159x68mm)
Weight	11 lbs (5kg)
Wind Survival Rating	125 mph (200 km/h)
Wind Load (at 100 mph)	363 N (frontal F1) 160 N (lateral F2)
Flat Plate Equivalent Area	2.31 ft² (0.22 m²)
Connector Types (Female)	Type N, or 7/16 DIN
Materials: Antenna/Radome	Aluminium/ABS



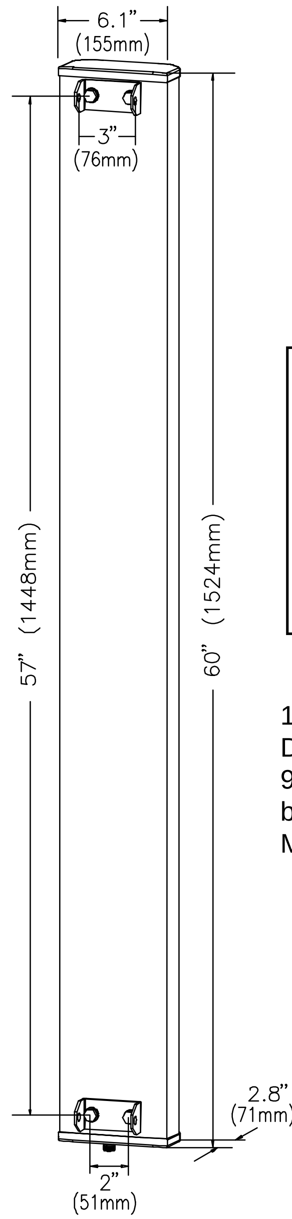
E-plane

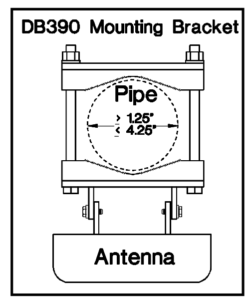
DAPA. Allegany, NY USA. Tel 1 800 325 3272. Int / l Tel +1 716 373 7228. Int / l Fax +1 716 373 5758

DB980H90(E/N/A/B/R/S)-KL

90°, 15 dBd Directional Antenna
1710-1880 MHz

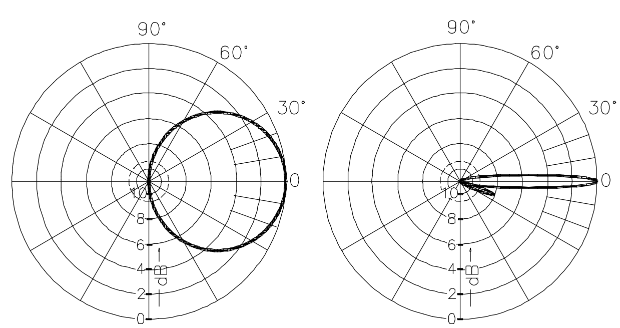
Model Number	DB980H90E-KL	DB980H90N-KL
	DB980H90A-KL	DB980H90B-KL
	DB980H90R-KL	DB980H90S-KL
Connector Options	Bottom: E = 7-16 DIN Back: A = 7-16 DIN Top: R = 7-16 DIN	N = Type N Female B = Type N Female S = Type N Female
Frequency Range	1710 - 1880 MHz	
Gain	15 dBd (17.1 dBi)	
Null Fill	First lower null is less than 18 dB down from max. First upper side lobe suppressed.	
VSWR	< 1.4:1	
Beamwidth (3dB from max)	Horizontal 90° ± 7° Vertical 5.5° ± .5°	
Front to Back Ratio	> 25 dB	
Polarization	Vertical	
Max. Input Power	250 Watts	
Application	PCN, PCS, DCS1800	
Weight	8.5 lbs (4.0 kg)	
Wind Area	2.5 ft² (.24 m²)	
Wind Load	100 lbf (445N) 44.9 kp (at 100 mph)	
Max. Wind Speed	165 mph (266 km/h)	
Material	Reflector Screen: Pass. Aluminum Radiators: Brass Radome: PVC, UV Resistant Mtg. Hardware: Galvanized Steel	
Color	Normal: Gray	
Mounting	DB390 pipe mount kit, included.	
Downtilt Brackets (Optional)	DB5098	
Weather Protection	Fully protected by backplate and radome.	
Lightning Protection	All metal parts grounded.	
Packing Size	72" x 7" x 6" (183 x 18 x 15 cm)	
Shipping Weight	15 lbs (6.8 kg)	





15 dBd (17.1 dBi) Gain Directional Antenna with 90° horizontal 3 dB beamwidth for 1710-1880 MHz.

Antenna Patterns



Horizontal Vertical

Electrical Downtilt (T) Option

Model Number	Downtilt	Gain (Main Lobe)
980H90T2E/N-KL	2°	15 dB

Specifications are for reference only. 099045-006 11/99E

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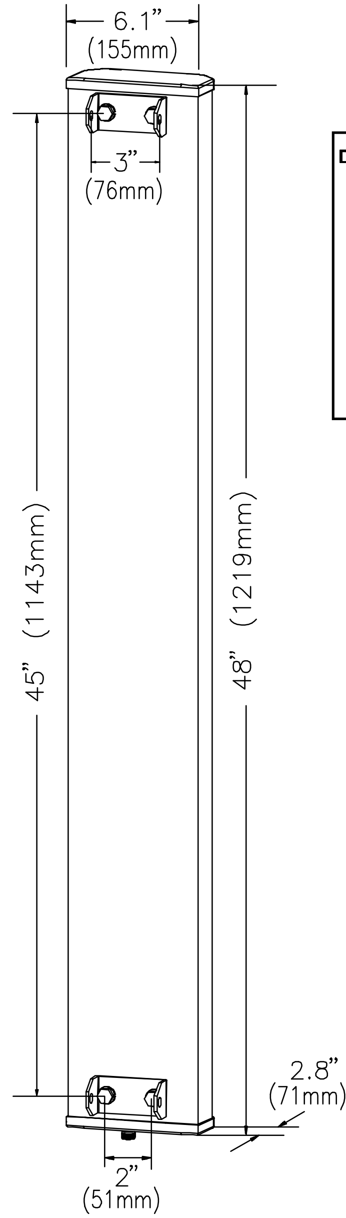
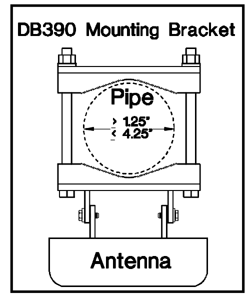
DB978H120(E/N/A/B/R/S)-KL

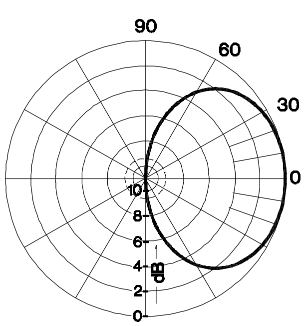
120°, 13 dBd Directional Antenna
1710-1880 MHz

Model Number	DB978H120E-KL	DB978H120N-KL
	DB978H120A-KL	DB978H120B-KL
	DB978H120R-KL	DB978H120S-KL
Connector Options	Bottom: E = 7/16 DIN Back: A = 7/16 DIN Top: R = 7/16 DIN	N = Type N Female B = Type N Female S = Type N Female
Frequency Range	1710-1880 MHz	
Gain	13 dBd (15.1 dBi)	
Null Fill	First lower null is less than 18 dB down from max. First lower side lobe suppressed.	
VSWR	< 1.4:1	
Beamwidth (3dB from max)	Horizontal: 120° ± 10° Vertical: 7° ± .5°	
Front to Back Ratio	> 25 dB	
Polarization	Vertical	
Max. Input Power	250 Watts	
Application	DCS1800	
Weight	7.1 lbs (3.2 kg)	
Wind Area	2.0 ft² (.19 m²)	
Wind Load	80 lbf (356N) 35.9 kp (at 100 mph)	
Max. Wind Speed	165 mph (266 km/h)	
Material	Reflector Screen: Radiators: Radome: Mtg. Hardware:	Pass. Aluminum Brass PVC, UV Resistant Galvanized Steel
Color	Normal: Gray	
Mounting	DB390 pipe mount kit, included.	
Downtilt Brackets (Optional)	DB5098	
Weather Protection	Fully protected by backplate and radome.	
Lightning Protection	All metal parts grounded.	
Packing Size	53" x 7" x 6" (135 X 18 X 15 cm)	
Shipping Weight	11 lbs (5 kg)	

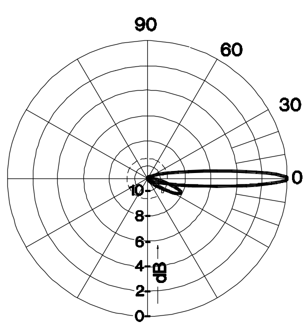




Antenna Patterns



Horizontal



Vertical

13 dBd (15.1 dBi) Gain Directional Antenna with 120° horizontal 3 dB beamwidth for 1850-1990 MHz.

Electrical Downtilt (T) Option

Model Number	Downtilt	Gain (dBd)
978H120T2E-KL	2°	13 dBd

Specifications are for reference only. 099050-009-A 11/99

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Annex D: Validation of interference powers computed at the orbital altitude of 35748 km

In order to provide a cross check of the interference levels computed via computer simulation a simple calculation can be performed. This calculation relates the range of interference power computed via simulation to the required the number of base stations required to produce this interference.

The starting point for this computation is the interference power from a single base station. Shown in Table 11 is the same parameters utilized for the simulation in §3, shown in Table 12 is the computation of the contribution from a single base station. Results indicate that the maximum contribution from a single station is –232.5 dBW/Hz and the minimum contribution is –247.6 dBW/Hz.

Table 11: Single base station input parameters.

Base Station Transmit Power	10	W
Peak Antenna Gain	17	dBi
Base Station Peak EIRP	27	dBW
Transmit Bandwidth	200	kHz
Peak Transmit EIRP density	-26.0	dBW/Hz
Frequency	1800	MHz
Peak l_2 loss	10	dB
Altitude	35748	km
Satellite Receive Gain	-5	dBi
Base Station Downtilt	2.5	degrees

Table 12: Computation of satellite receive power density from a single base station.

Elevation Angle (Deg)	Base Station Relative Gain (dB)	Transmit EIRP density (dBW/Hz)	Distance to Orbital Altitude (km)	l_2 loss (dB)	Free Space Loss (dB)	Satellite Receive Power Density (dBW/Hz)
0.0	-1.6	-27.6	41640.7	10.0	-189.94	-232.5
5.0	-12.4	-38.4	41088.5	10.0	-189.82	-243.2
10.0	-14.6	-40.6	40547.8	10.0	-189.71	-245.3
15.0	-16.1	-42.1	40022.5	10.0	-189.59	-246.7
20.0	-17.2	-43.2	39516.3	10.0	-189.48	-247.6
25.0	-18.0	-44.0	39032.2	8.8	-189.38	-247.2
30.0	-18.7	-44.8	38573.4	7.5	-189.27	-246.5
35.0	-19.4	-45.4	38142.6	6.3	-189.18	-245.8
40.0	-19.9	-45.9	37742.1	5.0	-189.08	-245.0
45.0	-20.4	-46.4	37374.0	3.8	-189.00	-244.2
50.0	-20.8	-46.8	37040.3	2.5	-188.92	-243.3
55.0	-21.2	-47.2	36742.3	1.3	-188.85	-242.3
60.0	-21.6	-47.6	36481.6	0.0	-188.79	-241.4
65.0	-21.9	-47.9	36259.3	0.0	-188.74	-241.7
70.0	-22.2	-48.2	36076.1	0.0	-188.69	-241.9
75.0	-22.5	-48.5	35933.0	0.0	-188.66	-242.2
80.0	-22.8	-48.8	35830.3	0.0	-188.63	-242.4
85.0	-23.0	-49.1	35768.6	0.0	-188.62	-242.7
90.0	-23.3	-49.3	35748.0	0.0	-188.61	-242.9

Simulation results from §3 indicate that at the 35748 km altitude the interference levels computed range from a maximum of –206 dBW/Hz to a minimum of –223 dBW/Hz. The minimum number of base stations contributing to the interference is therefore computed as

$$10^{(-223-(-232.5))/10} = 9.$$

The maximum number of base stations contributing to the interference could be as high as

$$10^{(-206-(-247.6))/10} = 14600.$$

These values are well within the number of base stations used in the simulation; in fact the total number of base stations simulated is 3808. This seems like a relatively low number but it should be noted that this is the total number of base stations of size 10 km transmitting with maximum power and represents an upper bound to the transmit power from each urban population center. It should be recognized that in this upper bound each 10 km base station represents up to 1007 base stations of smaller size.

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[iii] "The Global Demography Project," W. Tobler, U. Deichmann, J. Gottsegen and K. Maloy, Technical Report 95-6, University of California, Santa Barbara, April 1995.

[iv] 1990 Demographic Briefs, http://www.publicpurpose.com/dm-uad.htm

[v] Top 85 World Urbanized Areas: 1985: Population, Land Area & Density. http://www.publicpurpose.com/dm-iua85.htm

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[ix] "Urban Agglomerations, 1950-2015 (the 1996 revision)," United Nations Population Division, New York, NY, USA, 1996 (available on diskette).

[x] "Characteristics of IMT-2000," Industry working group on IMT-2000 characteristics, 1/5/01.

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APPENDIX B: Assessment of Interference from Mobiles Stations to Satellite Control Stations

1 Interference Methodology

Base stations are deployed in a cellular configuration in urban population centers to serve mobile users with communications services. For the purpose of this analysis, it is assumed that the aggregate co-channel emissions from an service area may be modeled as a single station that uses a transmitter with the power spectral density equal to the weighted sum of the power spectral density at the input to each mobile station in the service area, and that a single transmitting antenna provides an acceptable representation of the distribution of the e.i.r.p. spectral density above the local horizontal plane, for the case of mobile emissions this is assumed to be an omni directional antenna.

It has been assumed for these simulations that the aggregate emission from a single service area is proportional to the number of mobile stations in the urban population center.

The specific model used for the simulation is as follows. The power received from a distant transmitting station can be written as:

$$P_r = \frac{P_t G_t G_r}{l_1 l_2 l_3} \quad (1)$$

where:

- P_r = Received power spectral density at the output of an antenna in a specified frequency band (stated as a power spectral density for the purpose of this analysis (W/Hz));
- P_t = Transmitted power at the input to an antenna in the same frequency band specified for received power (stated as a spectral density for the purpose of this analysis (W/Hz));
- G_t = Gain of the transmitting antenna in the direction of the receiving station relative to an isotropic radiator (numeric);
- G_r = Gain of the receiving antenna in the direction of the transmitting station relative to an isotropic radiator (numeric);
- l_1 = Free-space propagation loss (numeric);
- l_2 = Loss in excess of free-space due to several stationary and time-dependent atmospheric effects (numeric);
- l_3 = Polarization coupling loss, equal to unity if the transmitting and receiving antennas are co-polarized.

The free-space propagation loss is:

$$l_1 = \left(\frac{4\pi d}{\lambda} \right)^2 \quad (2)$$

where

d = Distance between the transmitting and receiving stations in meters

λ = Wavelength in meters.

Each co-frequency transmitting station forms a radio link to the receiver. The received power from each of the *n* links, which are assumed to be transmitting uncorrelated signals, adds to form an aggregate received power given by:

$$P_r = \sum_{i=1}^{n} \frac{P_{ti} G_{ti} G_{ri}}{l_{1i} l_{2i} l_{3i}} \quad (3)$$

where the terms are as previously defined with the addition of a subscript, *i,* to denote each transmitting mobile station.

The aggregate interference is the sum of the interference from each transmitting station. The interference from each station is determined based on the transmitting and receiving antenna gains, taking into account the off axis angle of the respective antennas.

To speed the computation and taking into account that some terms are nearly constant for a single deployment area, Equation (3) is further refined as:

$$P_r = \sum_{i=1}^{m} \frac{G_{ti} G_{ri} \sum_{j=1}^{N_{bs}} \sum_{k=1}^{N_m} P_{tijk}}{l_{1i} l_{2i} l_{3i}} \quad (4)$$

where:

i = Summation index that denotes each city;

j = Summation index that denote each base station within city i;

k = Summation index that denote each mobile associated with base station, j, within city i;

N_m = Number of mobile stations communicating with base station j;

N_{bs} = Number of base stations in a specific deployment area i; and,

m = Number of deployment areas;

1.1 Metropolitan Area Contribution to the Interference Power

In order to assess the contribution to the interference from any metropolitan area the deployment of cellular systems is required. Two approaches have been suggested to estimate this deployment for future years; one is based solely on the population located within a metropolitan area and the other is based upon current deployment of cellular systems. The first approach is shown in §1.1.1

and is similar to that utilized in the analysis presented by the Department of Defense IMT-2000 Technical Working Group [i]. The second approach requires further development.

In general the system characteristics specify the maximum power supplied to the antenna of a mobile station. For the largest cell sizes utilized by the system this accurately represents the peak power. In areas requiring high capacity typically the cells are significantly smaller in radius, for these cases the mobile station transmit power should be reduced in order accurately model these areas. An approach to estimate this effect is shown in §1.1.2.

1.1.1 Relationship between Population and the Base Station Density

It has been found that the geographic area of an urban population center may be related to the total population with a degree of confidence. An empirical relationship between the radius in kilometers R_p of the circular area containing a total population P is given by [ii]

$$R_p = \alpha \times P^{\beta}. \tag{5}$$

This equation has been developed from observations of settlements ranging in size from about 150 people to over a million people. For the U.S., $\alpha = 0.035$ and $\beta = 0.44$ have been found to provide satisfactory results [ii]. A manual attempt to minimize the mean-squared error for this limited set of urban population centers occurs when the coefficient is 0.0355 and the exponent is 0.44. These are remarkably close to the values found in reference [ii].

For other areas of the world, the exponent has been found to be stable while there is some variation in the coefficient. The values of $\alpha = 0.015$ and $\beta = 0.44$ were found to minimize the mean-squared error for this data set. This corroborates the results reported in reference [ii] that a somewhat smaller value of α has been shown to apply to some other cultures that characteristically have more compact towns.

Equation (6) may be used to estimate the number of base stations of a particular size and deployment factor required to serve an area encompassing the total population. Assuming that each base station serves a circular area of radius R_h, the maximum possible number of base stations, $N(R_h)$, will be

$$N(R_h) = Int\left(\eta\left(\frac{R_p}{R_h}\right)^2 + T_{R_h}\right) \tag{6}$$

where:

$N(R_h)$ = Number of base stations for the assumed radius of the cell;

$Int(\ )$ = Indicates the integer value of the argument;

R_p = Equivalent radius of the urban area (km);

R_h = Radius of a typical BS cell (km);

η = $\eta_{R_h}\eta_p$ = Deployment factor; and,

T_{R_h} = Round off factor for cell radius R_h , valid values are $0.5 \le T_{R_h} < 1.0$.

The round off factor, T_{R_h}, ensures for cities with a small population that a cell site is located to provide coverage, possible values for cells of 315 m, 1 km and 10 km are respectfully 0.5, 0.5 and 0.9994 (the latter value ensures that cities with population as low as 850 would be covered by a 10 km cell site). The deployment factor has two aspects the first, η_{R_h}, accounts for relative number of a particular size of cell and the second, η_p, accounts for the penetration of cellular deployment in an area. To illustrate the factor η_{R_h} consider 3 cells size with a cell radius of 315 m, 1 km, and 10 km. Relationships between the sizes of the cells may be as found in Figure 1. In densely populated areas one would expect that the smaller cells would dominate the deployment and in less densely populated areas the larger cells will dominate. Note that the sum of this factor for all of the cell sizes considered must be 1.

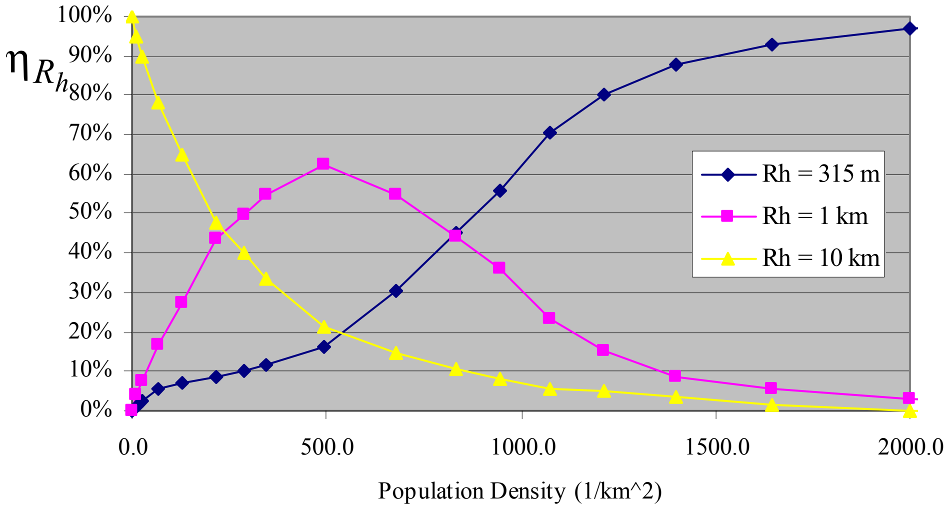

Figure 1: Example deployment factor η_{R_h} for 3 cell sizes of 315 m, 1 km and 10 km.

The factor that accounts for penetration, η_p, represents the maturity of a system in an area, values closer to 1 represent full coverage of the area and values closer to 0 represent no coverage in an area. Shown in Figure 2 is an example penetration factor for cell systems.

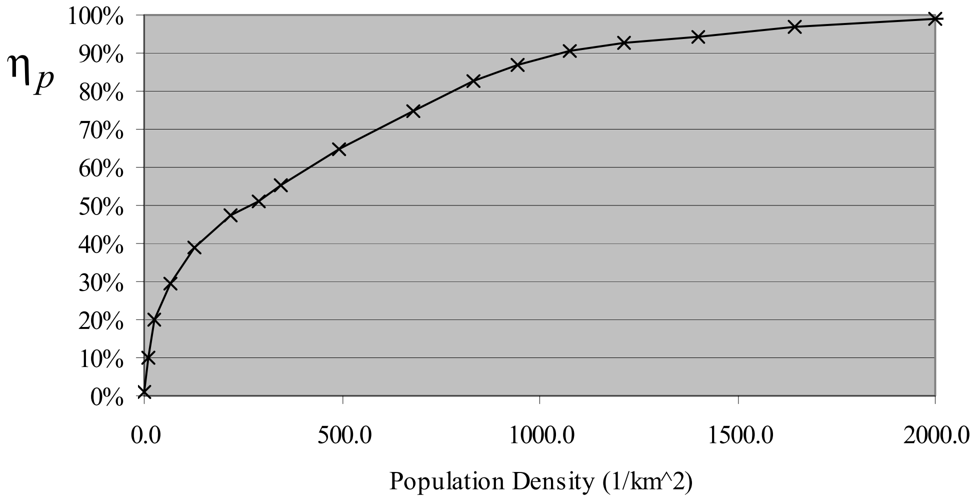

Figure 2: Example penetration factor η_p.

The representation in Figure 2 indicates the relationship to the local environment classifications of Urban, Suburban and Rule areas. Shown in Table 1 is the corresponding mobile penetration if the classifications of Urban (greater than 1070 people per km^2), Suburban (greater than 420 people per km^2) and Rural (greater than 10 people per km^2) are utilized.

Table 1: Penetration and population density to environment classification.

Local Environment	Population Density (per km^2)	Mobile Penetration η_p
Urban	1070	90%
Suburban	420	60%
Rural	10	10%

The total number of base stations is the sum over all sizes of base stations

$$N_{bs} = \sum_{R_h} N(R_h) \tag{7}$$

1.1.2 Transmit power from a deployment area with various sizes of cells

Data provided for the characteristics of mobile stations specify the maximum power supplied to the antenna. For the largest cell sizes utilized by the system this accurately represents the peak power radiated by a mobile, for mobiles operating in cells that are smaller in radius the power will be reduced. For this analysis it is assumed that the power is reduced as the square of the distance, this is represented as

$$P_m(R_h) = P_m(R_{h\,\max})\left(\frac{R_h}{R_{h\,\max}}\right)^2 \tag{8}$$

where:

$P_m(R_h)$ = Maximum transmit power for a mobile operating in a cell of radius R_h; and

$R_{h\max}$ = Maximum cell radius under consideration for analysis.

In order to represent this aspect the average peak power transmitted in a deployment area is computed as

$$\hat{P}_{tij} = \sum_{k=1}^{N_m}\left(\frac{P_m(R_{h\max})}{N_{bs}}\sum_{R_h}\left(N(R_h)\left(\frac{R_h}{R_{h\max}}\right)^2\right)\right)$$
$$= \frac{N_m P_m(R_{h\max})}{N_{bs}}\sum_{R_h}\left(N(R_h)\left(\frac{R_h}{R_{h\max}}\right)^2\right) \quad (9)$$

where:

$P_{\max} = P_m(R_{h\max})$ = Maximum transmit power supplied to the antenna input.

Utilization of the average peak transmit power in equation (4), the power received by the satellite can then be computed as

$$P_r = \sum_{i=1}^{m}\frac{G_{ti}G_{ri}\hat{P}_{tij}N_{bs}}{l_{1i}l_{2i}l_{3i}} \quad (10)$$

This representation results in an overestimate of the power radiating from an urban area due to the assumption that all of the mobile stations will be radiating at the maximum power level required for the specific cell size. Table 2 illustrates an example of computing $\hat{P}_{tij}$ for a city of population 140,000 located in the US utilizing the parameters found in the above figures for η_p and η_{R_h}.

Table 2: Example of computing $\hat{P}_{tij}$ for a city of size 140,000.

R_p	6.4 km			
Population density	1077/km^2			
	$R_h = 315m$	$R_h = 1km$	$R_h = 10km$	
η_p	91% =	91%	91%	
η_{R_h}	71%	24%	6%	
$N(R_h)$	266	9	1	$N_{bs} = 276$
$\hat{P}_{tij}$	0.0049 $N_m P_{\max}$			
$\hat{P}_{tij}N_{bs}$	1.3524 $N_m P_{\max}$ Total Power Supplied to Ant.			

2 Illustrative example

An input parameter to the methodology is a database of urban population an since the analysis is intend to give an upper bound to the interference for future use of IMT-2000 systems two possible sets of data are considered. In section 2.1 results are presented based upon the population projected for the year 2015. This data set contains only urban populations larger than 750,000, which for this database there are a total of 431 urban locations representing a population of 1.481 billion.

In order to more closely relate to the database of urban population utilized in the DoD interim report a database from the United Nations Demographic Yearbook 1995 is utilized [iii]. This database contains 3,312 major cities or urban agglomerations including capital cities and cities with more than 100,000 population. The worldwide population count for this database is 1.642 billion. Analysis results for this database are contained in section 2.2. For comparison the database utilized in the DoD interim report contained 2763 urban locations [i] and represented a population of 1.333 billion [iv].

2.1 United Nations population estimates for the year 2015

To illustrate the results obtained by applying the methodology found in section 2 a database of 431 urban population centers with a population estimated by the United Nations to exceed 750,000 people in the year 2015 is utilized [v]. Parameters required for the simulation are found in Table 4.

The approach utilized to estimate the power radiating from a metropolitan area is based on population density (see §1.1.1). Annex A shows that an upper bound to the power radiating from a metropolitan area can be found. The benefit of utilizing this upper bound is that specific relative deployment factors for each base station size is no longer required, i.e. the factor η_{R_h} can be ignored. This upper bound is found when the following assumptions are utilized:

1) Mobiles are assumed to be operating only within base stations with the smallest radius throughout the metropolitan area;
2) The number of base stations required to cover the city must be increased by the square of the ratio of each cell size considered to the smallest cell size.

Shown in Table 3 is the calculation of the parameter $\hat{P}_{tij}$ used in the upper bound to the power radiating from an urban area utilizing the table of characteristics specified by the industry working group [vi].

Table 3: Calculation of $\hat{P}_{tij}$.

		CDMA-2000	CDMA-2000	W-CDMA	UWC-136	Note:
Maximum EIRP	dBW	-6.02	-6.02	-6.02	0	1
Carrier Spacing	MHz	1.25	3.75	5	0.2	1
Scale EIRP to cell size of 315 m	dBW	-36.05	-36.05	-36.05	-30.03	
Users Per Cell Per MHz		214	214	214	214	2
BW Factor		3.20	1.07	0.80	20.02	
Number of channels to span 4.004 MHz		4	2	1	21	
Total BW	MHz	5	7.5	5	4.2	3
Active number of users		1070	1605	1070	112	
$\hat{P}_{tij}$	dBW/Hz	-72.75	-72.75	-72.75	-75.76	

The simulation is performed for altitudes of 250 km, 833 km, 20200 km and 35748 km above the earth for all locations in a 2-degree grid in latitude and longitude. Furthermore, in order to assess the differential impact that operations in the US can have, the simulations are performed with all cities in the database and for all cities minus those located in the US (the database contains 45 cities located in the US with population of 750,000 in the year 2015). The peak power received by a satellite at these altitudes is found in Table 5. The specific received powers are found in Figure 3 through Figure 7.

Table 4: Parameters utilized in this example.

Parameter	Value	Note
$\hat{P}_{tij}$	-72.75 dBW/Hz	Computed from parameters found in [vi] for a CDMA-2000, W-CDMA and TD-CDMA; UWC-136 Mobile Station with 200 kHz operating bandwidth result in lower transmit power densities.
G_{ri}	-5 dBi	Receive system gain from [vi].
l_{2i}	10	From [vii], due to environmental losses.
l_{3i}	0	Assumes co-polarization between signals.

[1] From Table 1 of Characteristics document.

[2] From Table 3 of Characteristics document during busy hour for 315m cells.

[3] For UWC-136 adjustment includes 8-time slots per TDMA frame.

Table 5: Summary of Peak Received Power

Altitude (km)	Peak received power to satellite communicating with earth stations over CONUS (dBW/Hz)	Peak Received Power (dBW/Hz)		
		All Cities	No US	Increase due to US
250	-186.6	-183.8	-184.2	0.4
833	-193.3	-189.3	-189.7	0.4
20200	-209.3	-209.3	-209.7	0.4
35748	-213.5	-213.5	-214.3	0.8

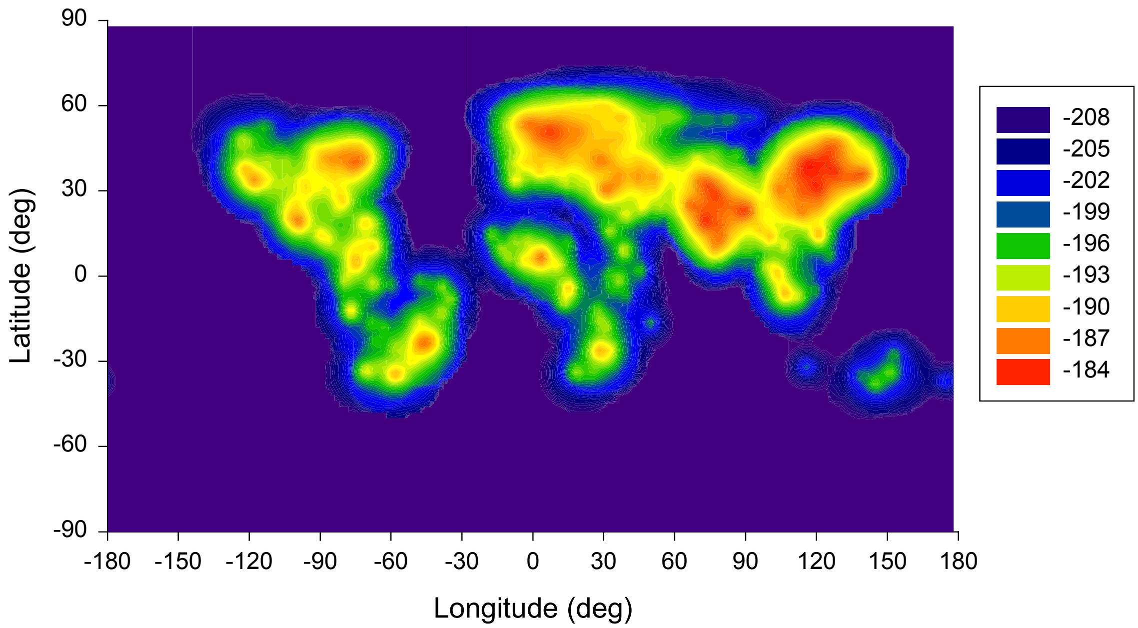

Figure 3: Spectral power (dBW/Hz) received by satellite at an altitude of 250 km (All Cities).

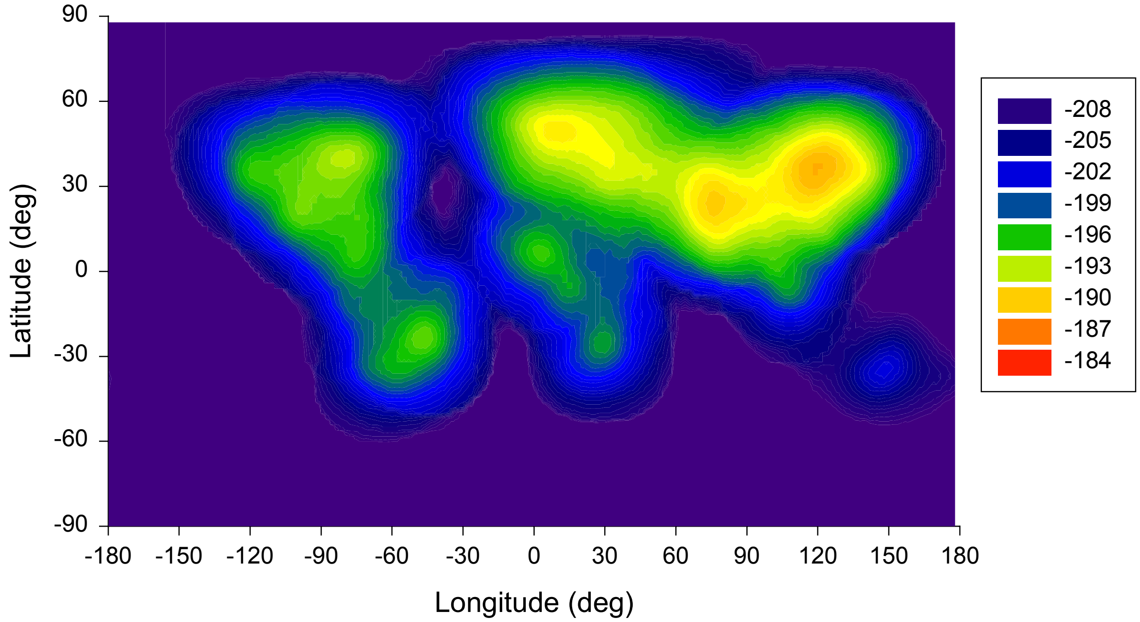

Figure 4: Spectral power (dBW/Hz) received by satellite at an altitude of 833 km (All Cities).

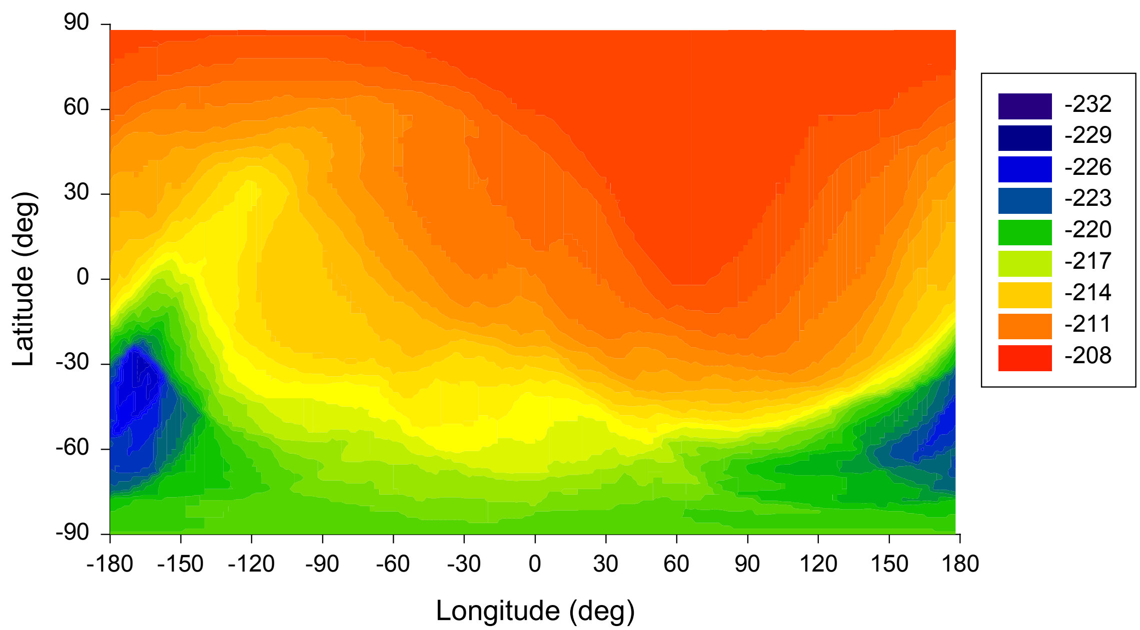

Figure 5: Spectral power (dBW/Hz) received by satellite at an altitude of 20200 km (All Cities).

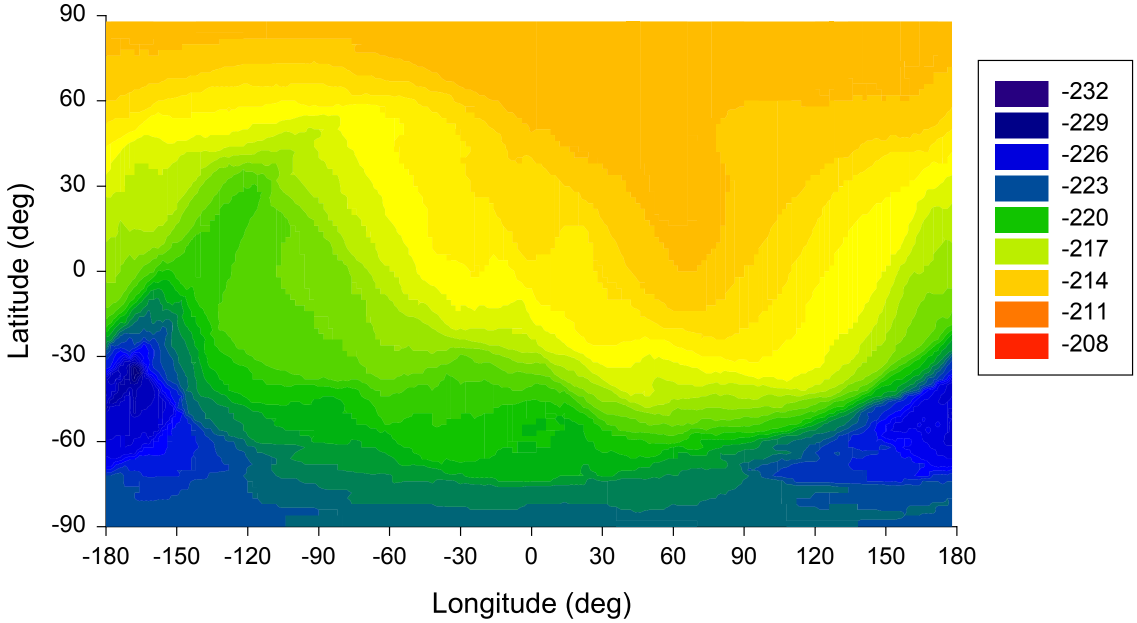

Figure 6: Spectral power (dBW/Hz) received by satellite at an altitude 35748 km (All Cities).

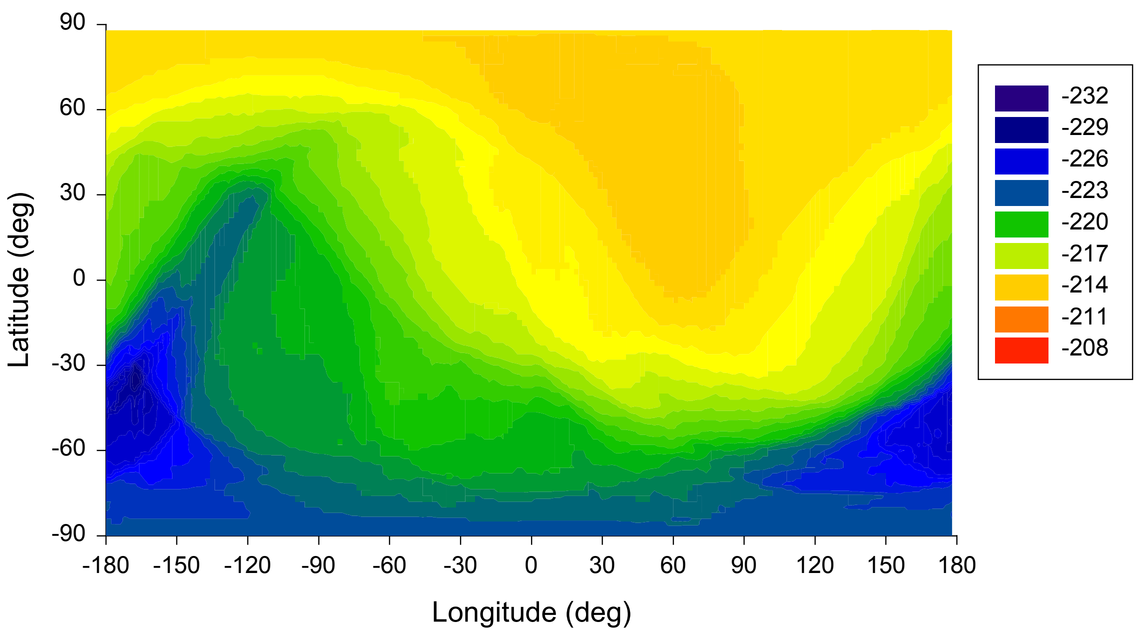

Figure 7: Spectral power (dBW/Hz) received by satellite at an altitude of 35748 km (No US).

2.2 United Nations Demographic Yearbook 1995

Results in this section are obtained by applying the methodology found in section 2 to a database of 3312 urban population centers with a population from the United Nations Demographic Yearbook 1995 [iii]. Parameters required for the simulation are found in Table 4.

The simulation is performed for altitudes of 250 km, 833 km, 20200 km and 35748 km above the earth for all locations in a 2-degree grid in latitude and longitude. Furthermore, in order to assess the differential impact that operations in the US can have, the simulations are performed with all cities in the database and for all cities minus those located in the US (the database contains 209 cities located in the US). The peak power received by a satellite at these altitudes is found in Table 6 along with the peak power that a satellite will receive when communicating with earth stations located in CONUS. The specific received powers are found in through Figure 8 through

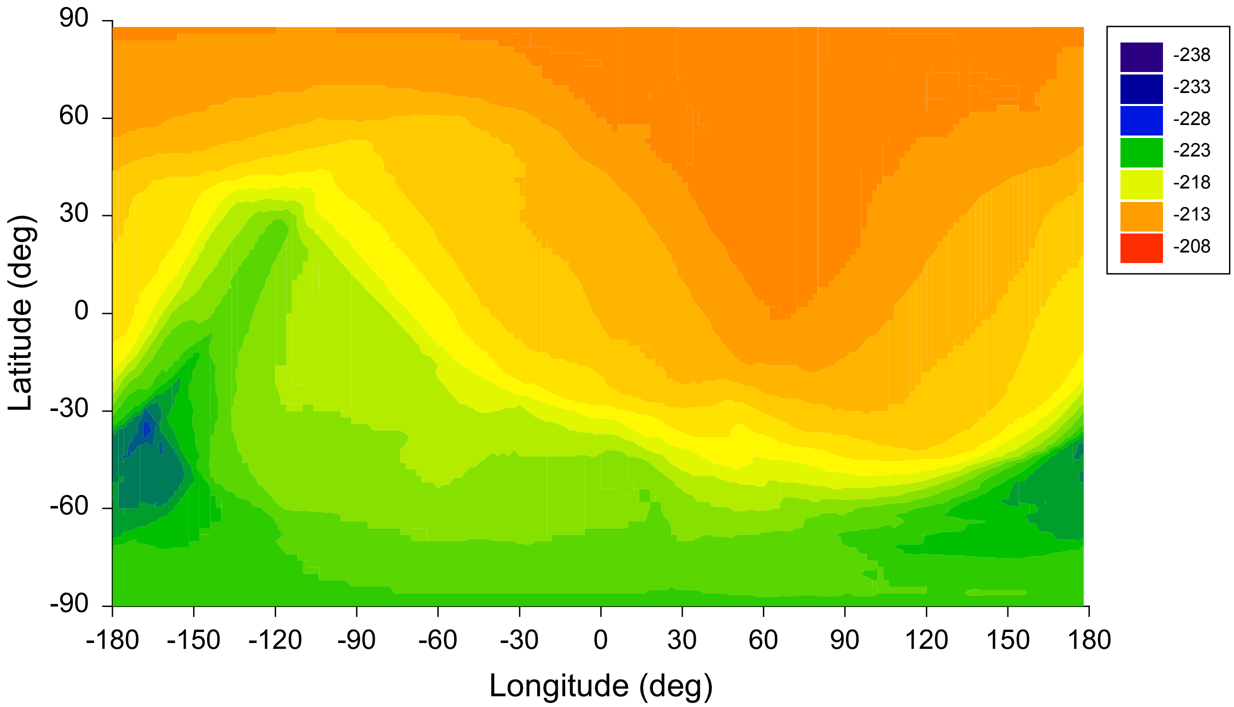

Figure 12.

Table 6: Summary of peak power received.

Altitude (km)	Peak received power to satellite communicating with earth stations over CONUS (dBW/Hz)	Peak Received Power (dBW/Hz)		
		All Cities	No US	Increase due to US
250	-185.0	-182.5	-182.5	0.0
833	-191.2	-187.5	-187.5	0.0
20200	-208.6	-208.6	-208.9	0.3
35748	-212.3	-212.3	-212.8	0.5

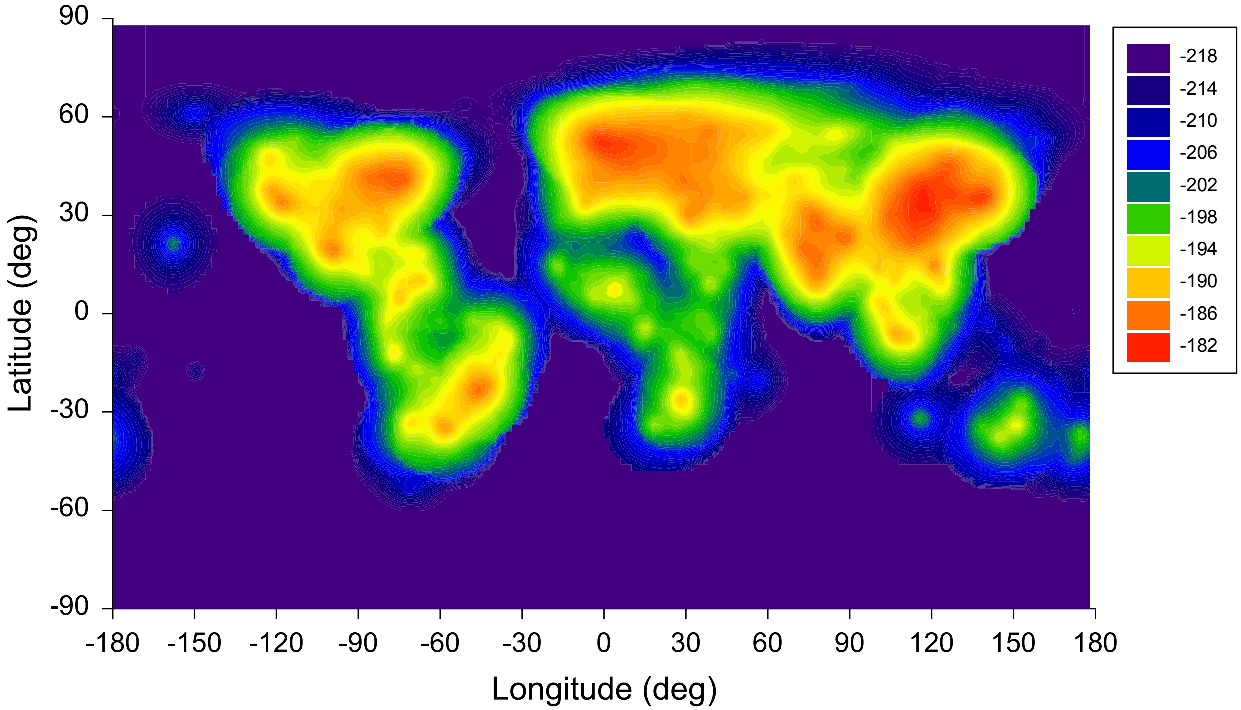

Figure 8: Spectral power (dBW/Hz) received by satellite at an altitude of 250 km (All Cities).

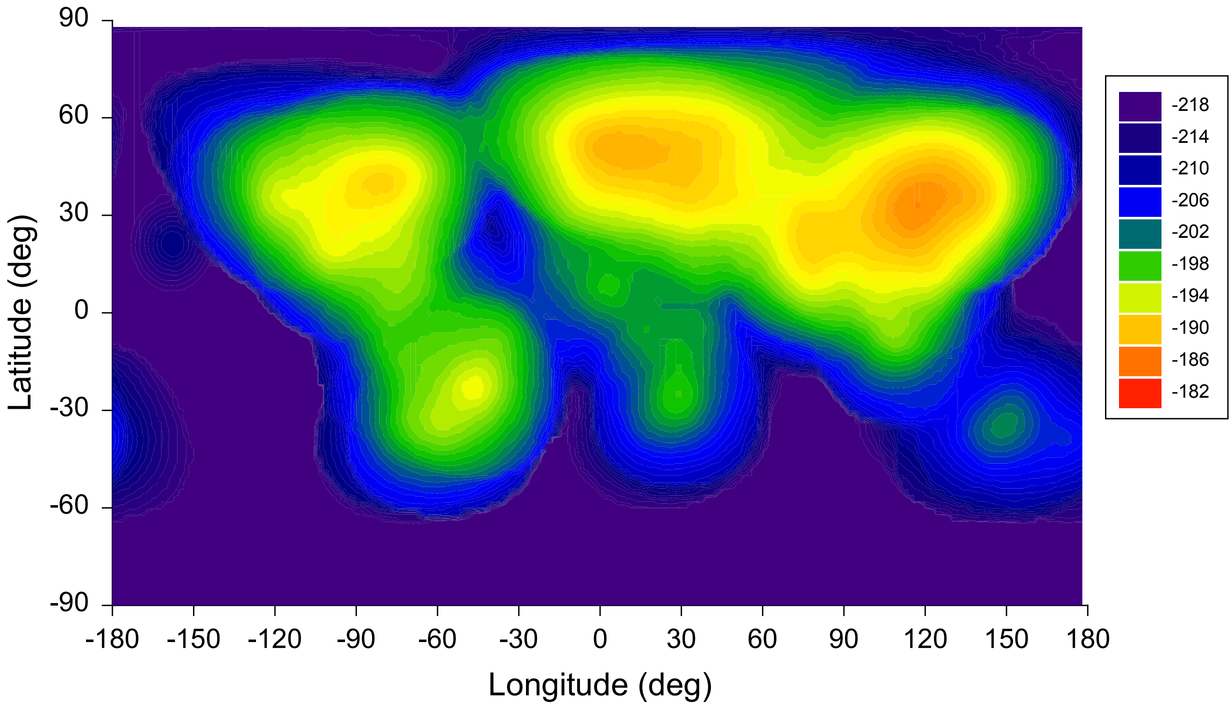

Figure 9: Spectral power (dBW/Hz) received by satellite at an altitude of 833 km (All Cities).

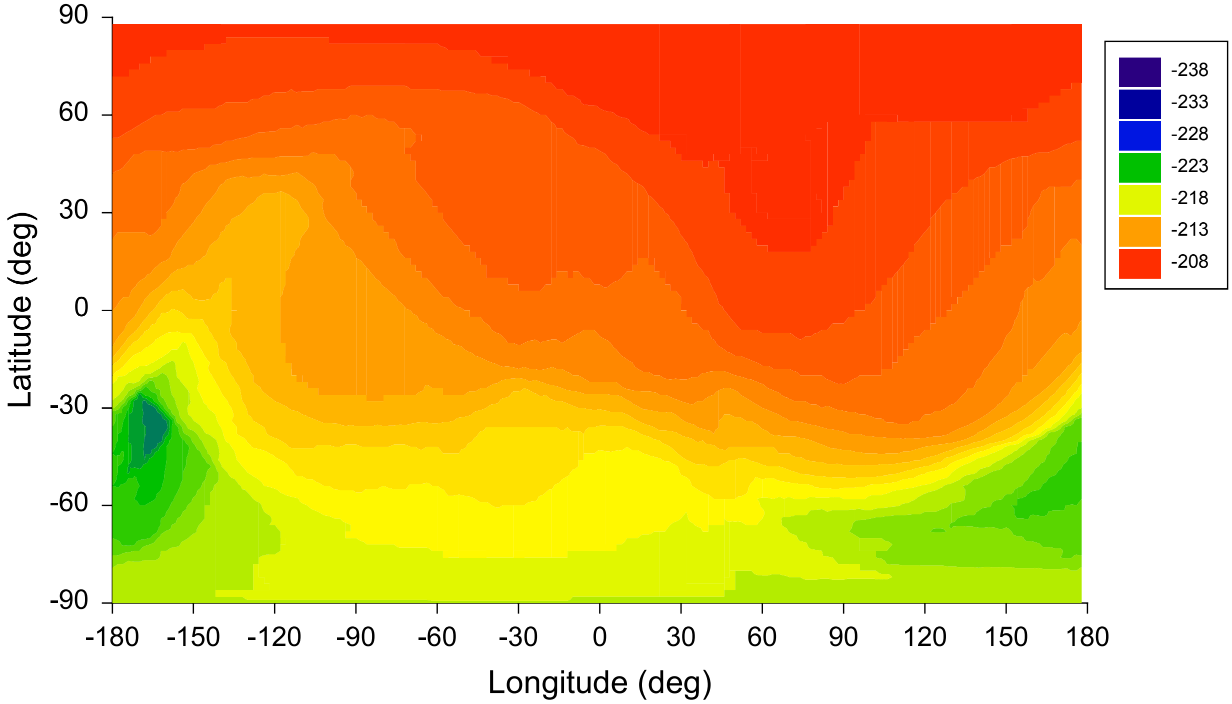

Figure 10: Spectral power (dBW/Hz) received by satellite at an altitude of 20200 km (All Cities).

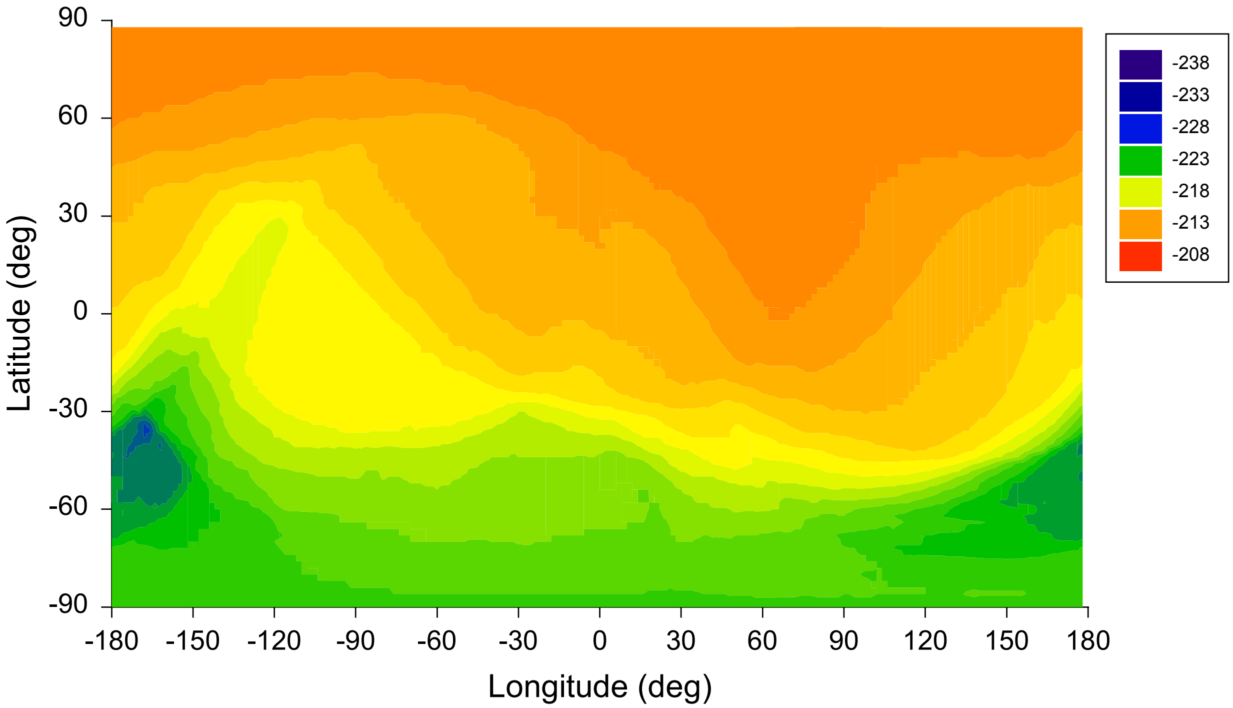

Figure 11: Spectral power (dBW/Hz) received by satellite at an altitude of 35748 km (All Cities).

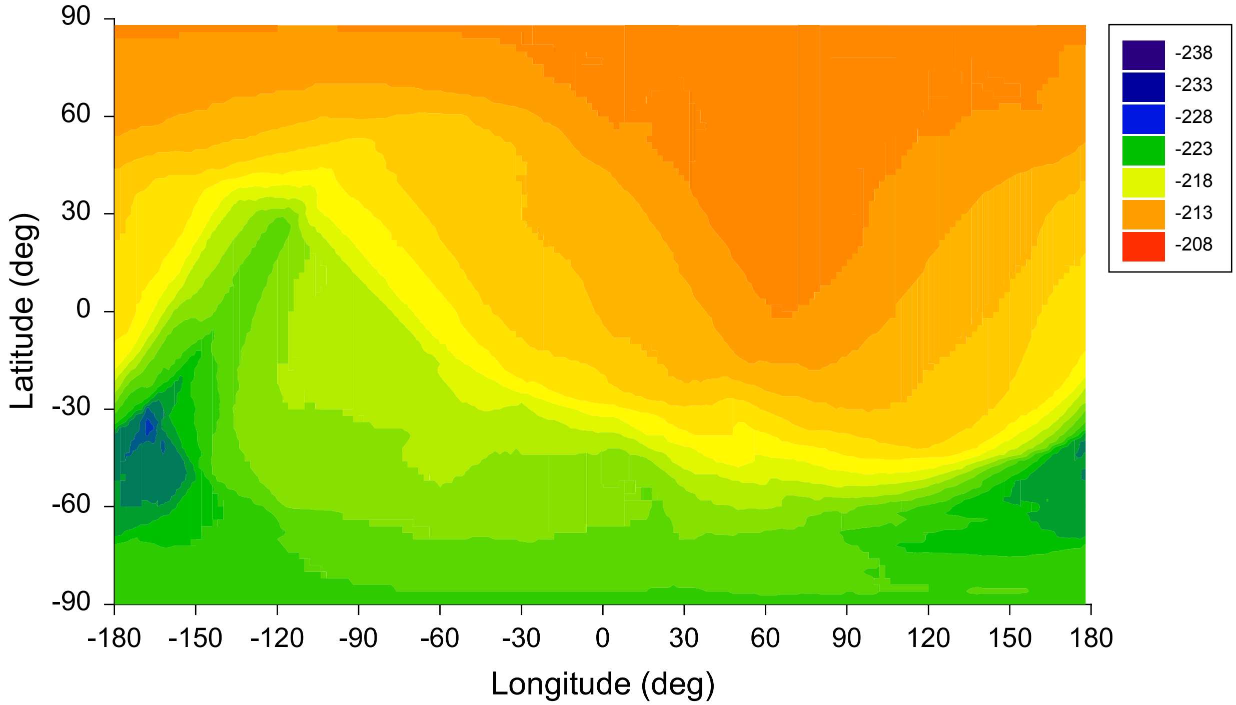

Figure 12: Spectral power (dBW/Hz) received by satellite at an altitude of 35748 km (No US).

ANNEX A

The total power radiating from a metropolitan area, *i,* is computed as the summation of the transmit power of all mobile stations located in this area, this is represented as:

$$P_{ti} = \sum_{j=1}^{N_{bs}} \sum_{k=1}^{N_m} P_{tijk} = \sum_{R_h} \left(N(R_h) \sum_{k=1}^{N_m} P_m(R_h) \right) \qquad \text{(D-1)}$$

where:

$N(R_h)$ = Number of base stations with radius R_h; and

$P_m(R_h)$ = Transmit power for mobile station operating in a cell radius of R_h.

The goal of this annex is to arrive an upper bound to the power radiated from a metropolitan area when applying a population-based approach in computing this power as found in §1.1.1. The benefit of utilizing this upper bound is that specific relative deployment factors for each base station size is no longer required, i.e. the factor η_{R_h} can be ignored. It is shown below that this upper limit is found when the following assumptions are utilized:

3) Mobiles are assumed to be operating within base stations with the smallest radius throughout the metropolitan area;
4) The number of base stations must be increased by the square of the ratio of each cell size to the smallest cell size.

To show this the following inequality must hold

$$\left(N'(R_{h\min}) + \sum_{R_h} \left(\frac{R_h}{R_{h\min}} \right)^2 \right) \sum_{k=1}^{N_m} P_m(R_{h\min}) \geq \sum_{R_h} \left(N(R_h) \sum_{k=1}^{N_m} P_m(R_h) \right) \qquad \text{(D-2)}$$

where

$N'(R_{h\min})$ = Number of base stations required to cover metropolitan area under the condition that only base stations of size $R_{h\min}$ are utilized.

In equation (D-2) the values $N(R_h)$ and $P_m(R_h)$ are computed as found in §1.1.2 above. Upon making the substitution of the above equation (8) and assuming that each cell size has the same number of transmitting mobiles, N_m, equation (D-2) now is

$$\left(N'(R_{h\min}) + \sum_{R_h} \left(\frac{R_h}{R_{h\min}} \right)^2 \right) N_m P_m(R_{h\min}) \geq \sum_{R_h} \left(N(R_h) N_m P_m(R_{h\max}) \left(\frac{R_h}{R_{h\max}} \right)^2 \right) . \text{(D-3)}$$

The inequality becomes

$$\cdot\left(N'(R_{h\min})+\sum_{R_h}\left(\frac{R_h}{R_{h\min}}\right)^2\right)\geq\sum_{R_h}\left(N(R_h)\left(\frac{R_h}{R_{h\min}}\right)^2\right) \quad \text{(D-4)}$$

Which becomes, after application of equation (6),

$$Int\left(\eta_p\left(\frac{R_p}{R_{h\min}}\right)^2+T_{R_{h\min}}\right)+\sum_{R_h}\left(\frac{R_h}{R_{h\min}}\right)^2\geq\sum_{R_h}\left(Int\left(\eta_{R_h}\eta_p\left(\frac{R_p}{R_h}\right)^2+T_{R_h}\right)\left(\frac{R_h}{R_{h\min}}\right)^2\right) \quad \text{(D-5)}$$

and can be expressed as

$$\eta_p\left(\frac{R_p}{R_{h\min}}\right)^2+T_{R_{h\min}}+\sum_{R_h}\left(\frac{R_h}{R_{h\min}}\right)^2\geq\sum_{R_h}\eta_{R_h}\eta_p\left(\frac{R_p}{R_{h\min}}\right)^2+\sum_{R_h}T_{R_h}\left(\frac{R_h}{R_{h\min}}\right)^2 \quad \text{(D-6)}$$

Since the only variable dependant upon R_h in the first summation on the right side is η_{R_h} and $\sum_{R_h}\eta_{R_h}=1$, this inequality becomes

$$\eta_p\left(\frac{R_p}{R_{h\min}}\right)^2+T_{R_{h\min}}+\sum_{R_h}\left(\frac{R_h}{R_{h\min}}\right)^2\geq\eta_p\left(\frac{R_p}{R_{h\min}}\right)^2+\sum_{R_h}T_{R_h}\left(\frac{R_h}{R_{h\min}}\right)^2. \quad \text{(D-7)}$$

Which is

$$T_{R_{h\min}}+\sum_{R_h}\left(\frac{R_h}{R_{h\min}}\right)^2\geq\sum_{R_h}T_{R_h}\left(\frac{R_h}{R_{h\min}}\right)^2. \quad \text{(D-8)}$$

Since $T_{R_h}<1$ the inequities above are true.

In order to illustrate the extent of this upper bound the example utilized in §1.1.2 is shown in Table 7. This example demonstrates that this upper bound over estimates the power radiating from a metropolitan area by 0.1 dB.

Table 7: Illustration of upper bound to the total transmit power

City Population	R_p (km)	Pop. Density (1/km^2)	η_p	Pmax (dBW/Hz)
140,000	6.4	1077.1	0.905	-53
Total power from metro area via approach in section 2.2.2				
R_h	η_{R_h}	T_{R_h}	$N(R_h)$	$N_m P_m(R_h)$
0.315	0.706	0.5	266	9.9e-4 $N_m P_{\max}$
1	0.236	0.5	9	1.e-2 $N_m P_{\max}$
10	0.058	0.9994	1	$N_m P_{\max}$
$\widehat{P}_{tij}$	0.00491	$N_m P_{\max}$		
N_{bs}	276			
Total Power	-51.7+10*log(N_m)	dBW/Hz		
Total power from metro area via upper bound in Annex C				
$R_{h\min}$	$\eta_{R_{h\min}}$	$T_{R_{h\min}}$	$N'(R_{h\min})$	$\left(N'(R_{h\min}) + \sum_{R_h}\left(\frac{R_h}{R_{h\min}}\right)^2\right)$
0.315	1	0.5	374	1392.9
$\widehat{P}_{tij}$	0.00099	$N_m P_{\max}$		
N_{bs}	1392.9			
Total Power	-51.6+10*log(N_m)	dBW/Hz		
Over estimate	**0.1**	**dB**		

[i] “Investigation of the technical feasibility of accommodating the international mobile telecommunications (IMT) 2000 within the 1755-1850 MHz band,” Department of Defense IMT-2000 Technical Working Group, Interim Report, 27 October 2000.

[ii] “The Global Demography Project,” W. Tobler, U. Deichmann, J. Gottsegen and K. Maloy, Technical Report 95-6, University of California, Santa Barbara, April 1995.

[iii] “Demographic Yearbook 1995,” United Nations publication, Sales No. E/F.97.XIII.1.

[iv] “Analysis of major parametric differences between the DoD and industry models of IMT interference to SATOPS,” B. Pottorff, 2/14/01.

[v] “Urban Agglomerations, 1950-2015 (the 1996 revision),” United Nations Population Division, New York, NY, USA, 1996 (available on diskette).

[vi] “Characteristics of IMT-2000,” Industry working group on IMT-2000 characteristics, 1/5/01.

[vii] “Methodology for determining the on-orbit signal levels due to an aggregate IMT 2000 environment,” Distributed at 12/1/00 Government-Industry outreach meeting.

APPENDIX C: Assessment of Interference from Satellite Control Stations to IMT-2000 Systems

Industry-Government 3G Spectrum Committee
Satellite Working Group

Contribution

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1 Introduction

On October 27, 2000, the DoD IMT-2000 Technical Working Group released an Interim Report on the technical feasibility of accommodating the IMT-2000 within the 1755-1850 MHz band. Appendix C of the DoD IMT-2000 TWG Interim Report contained an analysis of potential interference from DoD satellite operations (SATOPS) into IMT-2000 systems. This document applies interference generated by TWG SATOPS Models from the Interim Report Table C-4 to IMT-2000 systems with the goal of estimating the impact of interference into IMT-2000 systems.

It was noted during industry outreach meetings that the interference simulations contained in the Interim Report were done without the inclusion of SATOPS operational factors such as the percentage of time SATOPS antennas spent at low elevations and other various operational factors. Without specific knowledge or guidance as to the nature of these operational factors, assumptions have to be made for these parameters. The key assumptions made in this document are listed in Table 1.

The assessment made in this document indicates that sharing between SATOPS and IMT-2000 systems is difficult but possible. Mitigation techniques such as constraining low elevation operations to remote sites may be required by SATOPS, and IMT-2000 systems may be required to accept reduced capacity, at least during off-peak hours, and possibly reduced cell size. Sharing between SATOPS and IMT-2000 systems can be enhanced by the employment of additional mitigation techniques, as mentioned in section 3. Without utilizing mitigation techniques, an IMT-2000 exclusion zone of approximately 150 km would be required around CTS, NHS B & DLT, and OAS stations and approximately 500 km would be required around NHS A and ECVF stations. Utilizing mitigation techniques will allow IMT-2000 exclusion zones to be greatly reduced.

2 Interference Assessment

SATOPS model data given in Table C-4 of the interim report indicates that the SATOPS ground stations are capable of emitting very high EIRP at low elevation angles. When located in a geographic area containing IMT-2000 systems, these high EIRPs can cause harmful interference. The percentage of time that these emissions take place is estimated in section 2.2.

2.1 Key Assumptions

The evaluation in this document makes several assumptions regarding the operational parameters of SATOPS and deployment parameters of IMT-2000 systems. The key assumptions used in the evaluation are shown in Table 1. The assumption is also made that IMT-2000 systems are capable of operating at reduced capacity with a 5MHz block of their spectrum knocked out for short periods of time. IMT-2000 operational characteristics such as the frequency of pilot tones, handoff algorithms, etc may make this assumption invalid, and make sharing with SATOPS extremely unlikely.

Table 1 Interference Impact Assumptions

SATOPS Assumptions
Uniform distribution of pointing angles, down to minimum elevation
Uniform distribution of SATOPS channel usage
Baseband filtering of SATOPS Ground Stations
Spherical symmetry of antenna patterns
Shielding of SATOPS terminals, 10dB attenuation at IMT-2000 terminals
5 MHz maximum emission bandwidth
SATOPS operate at minimum power (100 W)
IMT-2000 Assumptions
Minimum allocation of 2x15 MHz
Population-driven distribution of IMT-2000 Base Stations
Uniform distribution of IMT-2000 Mobiles
Uniform probability of IMT-2000 technologies i.e. CDMA-2000, W-CDMA, etc
Building blockage of 10 dB

The information contained within the Interim Report was assumed to be accurate, with the acknowledgement that the Interim Report contained a first-cut time-constrained analysis.

More complete information could provide a more accurate analysis of SATOPS interference impact on IMT-2000 could include data on:

- Distribution of SATOPS elevation angles
- Distribution of SATOPS channel usage
- Distribution of SATOPS EIRP

- SATOPS EIRP distribution by Time of Day
- Population distribution surrounding SATOPS Ground Stations
- Size of cells within the SATOPS beam
- IMT-2000 technology i.e. EDGE, W-CDMA, etc

2.2 Evaluation

2.2.1 Bandwidth Effects

Any assessment of interference should use equivalent bandwidths for the interferer and the victim system. For this assessment, all IMT-2000 bandwidths were converted to a 5 MHz bandwidth. The threshold conversion used is shown in Equation 1. The converted interference thresholds are shown in Table 2.

Equation 1

Threshold' = Threshold - 10log(BW/5 MHz) dB

Table 2 Interference Thresholds in a 5 MHz Bandwidth for IMT-2000 Mobiles

	CDMA-2000 1x	CDMA-2000 3x	UWC-136 30 kHz	UWC-136 200 kHz	TD-CDMA	W-CDMA
Threshold 1	-104 dBm	-103.7 dBm	-104.8 dBm	-105 dBm	-109.8 dBm	-105 dBm
Threshold 2	-88 dBm	-88.7 dBm	-88.8 dBm	-89 dBm	-90.8 dBm	-89 dBm

2.2.2 Propagation Model

The propagation model used for this evaluation was a simple free-space model. The equation for the model is shown in Equation 2.

Equation 2

Loss = 32.4 + 20*LOG(f) + 20*LOG(R)

Where:

f = frequency in MHz
R = distance in km

Evaluating propagation loss at 1800 MHz yields 125.5 dB at 25 km and 131.5 dB at 50 km.

2.2.3 Interference Criteria

Table 2 shows that most IMT-2000 systems interference thresholds can be represented by –105 dBm/5 MHz for threshold 1, and –90 dBm /5 MHz for threshold 2. Using the antenna patterns from the Interim Report, Figures C-3 through C-6 and the assumptions listed in Table 1, the angle at which SATOPS interference exceeds the thresholds in Table 2 can be calculated. The shortfall between the threshold and the interference power indicated the additional antenna discrimination needed. The additional discrimination was estimated from the antenna patterns shown in the Interim Report. The results of these calculations are shown in Table 3.

Table 3 Minimum Elevation Angle for Interference

				Threshold 1 = -105 dBm		Threshold 2 = -90 dBm	
	EIRP @ 5º	Power @ 25km	Power w/ shielding & blockage	Short fall dB	Min angle for interference (topocentric)	Shortfall dB	Min angle for interference (topocentric)
CTS	55	-70.5	-90.5	14.5	10	-	-
NHS A	67	-58.5	-78.5	26.5	30	11.5	20
NHS B	55	-70.5	-90.5	14.5	40	-	-
NHS DLT	55	-70.5	-90.5	14.5	10	-	-
OAS	55	-70.5	-90.5	14.5	Note 1	-	Note 1
ECVF	66	-59.5	-79.5	25.5	55	5.5	20

Note 1: No information for the OAS antenna was given in the Interim Report

2.2.4 SATOPS Pointing Angles

This section estimates the percentage of time in which SATOPS generates high levels of interference into IMT-2000 systems by assuming that all points of the sky above the minimum elevation angle are equally likely to be targeted. The angle at which SATOPS interference is greater than the IMT-2000 thresholds is calculated in section 2.2.3. The percent of time spent at elevation angles between the calculated interference angle and the minimum elevation angle can be estimated by estimating the percent of space between the angles and assuming an ergodic relationship between %space and %time.

The surface area of the partial sphere (spherical cap) having radius (6378km + orbital altitude) is calculated for the interference angles shown in Table 3. The calculation is made for the surface area of the spherical cap above the minimum elevation angle and repeated for the surface area above the interference angle. The surface area of a spherical cap is given by Equation 3.

Equation 3

$$S_{cap} = \int_0^{2\pi}\int_0^{\alpha} r^2 \cdot \sin(\gamma) d\gamma \cdot d\varphi$$

Where:

α = geocentric elevation angle

r = sphere radius, 6378km + orbit altitude

Evaluating the integrals in Equation 3 results in Equation 4.

Equation 4

$S_{cap} = 2\pi r^2 \cdot (1-\cos(\alpha))$

Equation 4 must be evaluated using geocentric angles, hence all topocentric elevation angles must be converted to geocentric angles using Equation 5 and Figure 1. The conversion results for the interference angles shown in Table 3 are listed in Table 4.

Equation 5

$\alpha = \text{acos}\ (\cos(\phi) * R/(R+A)) - \phi$

Where:

ϕ = topocentric angle
α = geocentric angle
R = mean Earth radius, 6378 km
A = orbit altitude

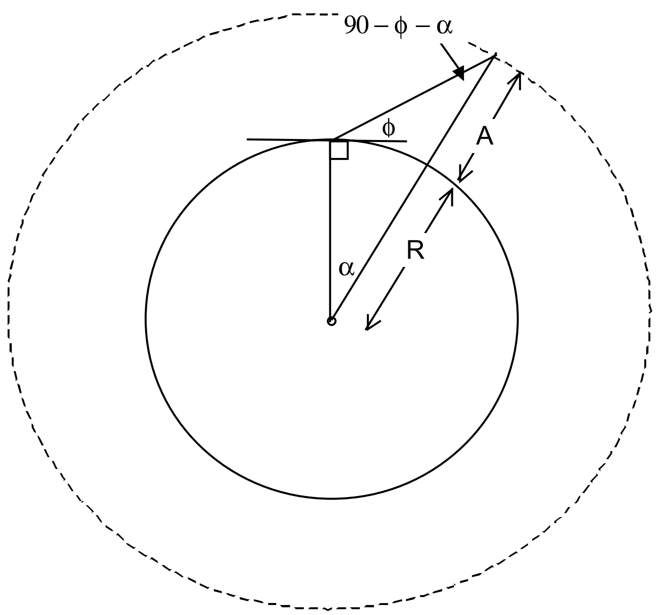

Figure 1 Satellite Angle Conversion Geometry

Table 4 Geocentric Angles

Topocentric Angle	Geocentric Angle			
	250	833	22200	35748
3	13.06	24.96	74.12	78.30
5	11.54	23.22	72.15	76.33
10	8.62	19.42	67.30	71.43
20	5.28	13.78	57.89	61.82
30	3.55	10.01	48.86	52.47
40	2.51	7.35	40.16	43.34
50	1.79	5.35	31.75	34.42
55	1.50	4.51	27.65	30.02

The %sky can be calculated by evaluating Equation 4 at the geocentric interference angle and dividing by the %sky above the minimum elevation angle. This yields the %sky above the interference angle.

Equation 6

$$\%Sky = (S_{cap > \text{interference angle}}) / (S_{cap > \text{minimum elevation angle}})$$

$$= [2\pi r^2 \cdot (1-\cos(\theta_{interference}))] / [2\pi r^2 \cdot (1-\cos(\theta_{min\ elevation}))]$$

$$= (1-\cos(\theta_{interference})) / (1-\cos(\theta_{min\ elevation}))$$

The results of the calculations for the interference angles listed in Table 3 are shown in Table 5. As can be seen from Table 3, threshold 2 is exceeded by NHS A and ECVF SATOPS terminals at angles below 20º. Table 5 shows that high percentages (> 50%) of the orbital shell is below 20º for low orbital altitudes. Threshold 1 is exceeded by NHS A, NHS B, and ECVF terminals for greater than 50% of the orbital shell at all altitudes. For these terminal types, an exclusion zone greater than 25km may be needed to facilitate sharing.

Table 5 Percent of Sky below Topocentric Interference Angle

Altitude (km)	**10º**	**20º**	**30º**	**40º**	**50º**	**55º**
250	44	79	90	95	98	98
833	29	64	81	90	95	96
22200	11	32	51	66	78	84
35748	11	31	49	64	77	82

3 Mitigation Considerations

There are numerous mitigation techniques that appear to offer the opportunity for SATOPS ground stations to coexist with IMT-2000 systems under certain conditions. These conditions include:

1. At least 15 MHz per IMT-2000 license
   15 MHz of spectrum may allow SATOPS interference to block 5MHz of spectrum in areas/times in which 3G systems do not require maximum capacity, without impacting 3G operations.
2. Baseband filtering of SATOPS ground station transmitters
   Baseband filtering ensures that SATOPS interference will be limited to 5MHz of spectrum at any one time. Without Baseband filtering, SATOPS interference is likely to be unacceptable to 3G operations under any conditions.

3.1 Relocation to Remote Areas

Relocation of SATOPS Ground Stations to locations with low capacity requirements may allow frequency sharing. If operators are licensed 2x15 MHz blocks in remote or lightly populated areas it is likely that SATOPS can block 5 MHz of spectrum at any given time without impacting 3G operations. Relocation may also allow for greater exclusion zones without impacting IMT-2000 system operations.

3.2 Time/Frequency Sharing

Since SATOPS ground stations use a single channel at any one time, time/frequency sharing may be possible. The SATOPS ground stations would need to limit their low-elevation angle operations to times of day/week when IMT-2000 systems have low utilization i.e. nighttime, and relocation to remote areas may be required.

3.3 Reduced SATOPS Maximum Power

Reducing maximum power on SATOPS ground stations that cannot be moved to remote locations may allow for some sharing with IMT-2000 systems, however, it is unlikely that this will allow sharing without being coupled with another mitigation technique, such as a limit on the minimum elevation angle, due to the high levels of interference.

3.4 Minimum Elevation Angles

A limit on the minimum elevation angles may offer an opportunity for sharing, however this assumes that SATOPS operations can be limited to higher elevation angles without operations being impeded. The %time that interference thresholds were exceeded were calculated for a minimum elevation angle of 5º. Increasing this elevation angle to 10º would reduce the amount of time that SATOPS exceeded the interference threshold of IMT-2000 systems.

Off-loading of low elevation angle operations to SATOPS ground stations in remote locations may allow 3G operations to tolerate SATOPS interference since off-peak capacity may be lower than in non-remote sites.

3.5 Limits on the Number of DoD Transmission Channels

The Joint Spectrum Center stated that the DoD satellites are hard-wired for a single frequency, with some satellites having the capability of tuning between two frequencies. Since any SATOPS ground station must be capable of communicating with any satellite, this mitigation technique is not considered to be a viable option.

3.6 Baseband Filtering

Unless all SATOPS operations requiring low elevation angles can be moved to sites with no 3G systems, which is unlikely since 3G systems are expected to be ubiquitous, baseband filtering would be required for any sharing scenario to be viable. All mitigation techniques that would require low-elevation angle operations to be moved to remote locations assume that only a single channel would be affected and that the remote location off-peak capacity requirements are sufficiently low such that the 3G operators could tolerate the loss of a 5 MHz channel for short periods of time. Without Baseband filtering, a much larger block of spectrum will be lost to interference, which would be intolerable to the 3G industry unless SATOPS could be moved to a location in which a large exclusion zone (> 100km) could be tolerated.

3.7 Shielding

Shielding of SATOPS ground station antennas could limit the spread of energy and may offer the opportunity for sharing with IMT-2000 systems. The calculations in Table 5 were based on an attenuation of 10 dB accomplished by shielding of SATOPS sites.

3.8 Cell Radius

The interference thresholds used in this assessment can be increased by a reduction in the IMT-2000 mean cell radius. Cooperative cell planning between IMT-2000 operators and DoD SATOPS may increase the probability of sharing by making IMT-2000 receivers less susceptible to interference.

4 Summary

The results of this interference assessment indicate that SATOPS will cause unacceptable interference into IMT-2000 systems for great distances. The interference is limited in time by operational parameters of SATOPS such as elevation angle. The percent of time that unacceptable interference will occur was determined to be low enough to consider time/frequency sharing. Time/frequency sharing would require SATOPS to constrain their low elevation angle operations to times of day in which IMT-2000 systems can operate at less than full capacity. It is also possible that SATOPS low elevation angle operations will need to be relocated to areas where IMT-2000 operations decrease significantly during nighttime.

This assessment only calculated interference into IMT-2000 mobiles. Base stations are ~4dB more susceptible to interference and are unlikely to be protected by the 10dB building blockage afforded to mobiles, leaving an additional 14 dB shortfall. Base stations may benefit from the downward tilt and their antenna pattern by an estimated 9-

10 dB over mobiles, leaving only a 4-5 dB shortfall. An accurate estimate of the interference impact on base stations would require a terrain dependent simulation such as was done in the Interim Report.

This assessment is considered to be conservative, since the propagation model used was a simple R^2 model, and the lower interference threshold is for mobiles at the edge of the cell. Terrestrial links are more likely to follow an R^4 propagation model, decreasing the effects of SATOPS interference into IMT-2000 systems, and building blockage will probably exceed 10 dB.

APPENDIX D: Report on the Potential for Relocation of US Government Satellite Uplinks from the 1755 - 1850 MHz Band to the 2025 - 2110 MHz Band

February 12, 2001

1 Introduction

One of the frequency bands under consideration for identification of spectrum for the accommodation of 3G terrestrial systems in the US is the band 1755 - 1850 MHz. This band is currently allocated on an exclusive basis to the Federal Government for fixed and mobile services. A footnote to the National Table of Frequency Allocations (FN G42) provides for the accommodation of space command, control, range and range-rate systems for earth station transmissions only (including installations on certain Navy ships) on a co-equal basis with the fixed and mobile services in the band 1761 - 1842 MHz.

In the NTIA report "Federal Operations in the 1755 - 1850 MHz Band" released on November 15, 2000, the uplink satellite control systems are identified as one of the most serious challenges in accommodating IMT-2000 systems in this frequency band. The Department of Defense (DoD) interim report "Investigation of the Technical Feasibility of Accommodating the International Mobile Telecommunications (IMT) 2000 within the 1755 - 1850 MHz band" released October 27, 2000 presents an EMC assessment of the interference between IMT-2000 systems and satellite uplinks.

One possible solution to overcome this interference situation is to relocate the uplink satellite control systems to another frequency band. One possible band is 2025 - 2110 MHz. This report will analyze the feasibility of relocating the Federal Government uplink satellite control systems from the 1755 - 1850 MHz band to the 2025 - 2110 MHz band.

2 System Description for the Satellite Uplink Operations

The DoD interim report gives the system description for the satellite uplink operations in the 1755 - 1850 MHz band. The interim report states that there are over 120 satellites flying in both geostationary and non-geostationary orbits that have uplink operations in the band 1761 - 1842 MHz. The Air Force Satellite Control Network (AFSCN) is a worldwide network of US Air Force ground stations and control centers that provide telemetry, tracking and commanding services to DoD satellites. The AFSCN consists of two control nodes: one at Schriever Air Force Base in Colorado and the other at Onizuka Air Station in Sunnyvale, California. Additionally, there are eight Automated Remote Tracking Stations (ARTS) dispersed both within and outside the US. It is noted that these primary sites are located at fixed locations. The Navy also operates Space Ground Link Subsystem (SGLS) at the following locations: Prospect Harbor, Maine; Laguna Peak, California; Finegayan, Guam; Blossom Point, Maryland; and Quantico, Virginia. Footnote G42 also identifies installations on certain Navy ships. There is no information available on these systems.

The DoD interim report gives the antenna patterns for antenna diameters of 60, 46, 33 and 23 feet. These patterns will be assumed in this report to be the typical patterns for all of the uplink earth stations.

3 Allocations in the Band 2025 - 2110 MHz

Internationally, the band 2025 - 2110 MHz is allocated on a primary basis to the space operation (Earth-to-space) (space-to-space), Earth exploration-satellite (Earth-to-space) (space-to-space), space research (Earth-to-space) (space-to-space), fixed and mobile services. With respect to the mobile services, footnote S5.391 says that administrations shall not introduce high-density mobile systems, as described in Recommendation ITU-R SA.1154, and shall take that Recommendation into account for the introduction of any other type of mobile system.

In the US, the primary allocations are the same as those internationally. The government allocations are to the space operation, Earth exploration-satellite and space research services and the non-government allocations are to the fixed and mobile services. There are several footnotes to the US Table of Allocations that are relevant to this report:

US222: In the band 2025 - 2035 MHz, GOES Earth stations in the space research and Earth exploration-satellite services may be authorized on a co-equal basis to use the frequency band 2025 - 2035 MHz for Earth-to-space transmissions for tracking, telemetry and telecommand at sites in Wallops Island, Seattle and Honolulu.

US346: Except as provided by US222, the use of the band 2025 - 2110 MHz by the Government space operation service (Earth-to-space), Earth exploration-satellite service (Earth-to-space) and space research service (Earth-to-space) shall not constrain the deployment of the Television Broadcast Auxiliary Service, the Cable Television Relay Service, or the Local Television Transmission Service. To facilitate compatible operations between non-Government terrestrial receiving stations at fixed sites and Government earth station transmitters, coordination is required. To facilitate compatible operations between non-government terrestrial transmitting stations and Government spacecraft receivers, the terrestrial transmitters shall not be high density systems (See Recommendations ITU-R SA.1154 and ITU-R F.1247).

US347: In the band 2025 - 2110 MHz, non-Government Earth-to-space and space-to-space transmissions may be authorized in the space research and Earth exploration-satellite services subject to such conditions as may be applied on a case-by-case basis. Such transmissions shall not cause harmful interference to Government and non-Government stations operating in accordance with the Table of Frequency Allocations.

NG118: In the band 2025 - 2110 MHz, television translator relay stations may be authorized to use frequencies on a secondary basis to other stations in the Television Broadcast Auxiliary Service that are operating in accordance with the Table of Frequency Allocations.

4 US Spectrum Usage in the band 2025 - 2110 MHz

The NTIA spectrum summary (dated August 22, 1997) for the band 2025 - 2110 MHz identifies several operations in this band.

The band is used heavily for Auxiliary broadcasting, Cable television, and Domestic public fixed services by TV broadcasters for one way transmission services such as: portable van and helicopter mounted transmissions of video from remote news events; studio-to-transmitter links; and, intercity relay of video programming.

NASA's global ground network and TDRSS operations from 2025 - 2110 MHz are essential to NASA's Earth exploration, space operations and space research activities. This use includes Earth-to-space and space-to-space transmissions. Over 50 US space missions, and, consistent with international agreements, additional foreign missions will be supported by NASA in the next 5 years. There will be varying degrees of support from launch and orbital transfer to full-time data relay. These telecommunications links are made available to private sector expendable launch vehicle operations. 123 satellites from 9 countries are planned for or are operational in the 2025 - 2110 MHz and 2200 - 2290 MHz bands. These missions comprise 341 planned or existing assignments, not including earth stations.

This band is also used for uplinks for the GOES weather satellite, supporting weather prediction efforts.

5 International Satellite Uplink Filings in the Band 2025 - 2110 MHz

The band 2025 - 2110 MHz is used by several geostationary and non-geostationary satellites, both domestically and internationally, for space operations (i.e., command, tracking, control and ranging). A search of the latest SRS (including the IFIC's up to 14 November 2000) found 208 satellites filed with uplink operations in the band 2025 - 2110 MHz. Of these, 136 are geostationary satellites and the other 72 are non-geostationary satellites. The orbital locations of the geostationary satellites and the frequencies that are used for each satellite are given in Table A1-1 of Annex 1. The table also includes the total bandwidth used by each geostationary satellite and the total percentage of the overall allocated band proposed to be used (i.e., the total bandwidth used / 85 MHz). The information on the non-geostationary satellites is given in Table A2-1 of Annex 2. The table gives the satellite name, inclination angle, apogee, perigee, the total bandwidth used and the total percentage of the overall allocated band proposed to be used.

For the geostationary systems, the total frequency used for uplink at all but 10 of the orbital locations is less than 17 MHz. There is approximately 22 MHz filed at one of the locations. For six of the locations (the GENESIS satellite series), the filing has 5 MHz-wide frequency bands across almost the entire band. It can probably be assumed that all of these frequencies will not be used. For 3 orbital locations, the entire band is filed. It is expected that these satellites will not use the entire band, but only a small portion of it once the final satellite design is implemented.

For the non-geostationary satellite systems, the total frequency usage of all of the satellites covers almost the entire frequency band, but there are relatively few satellite filed in any given part of the band.

It should be noted that the backlog data (i.e., filings received by the BR, but not yet published) is not included in these tables and would presumably add more satellites using the 2025 - 2110 MHz band for uplinks. It is expected that including these systems would increase the overall usage of the band, but the expected result is that there would still be several unused frequencies for any given geostationary orbital location and there would be relatively few non-geostationary satellites filed for any given frequency.

According to the NTIA interim report, there are 151 unclassified satellite systems with uplinks in the 1761 - 1843 MHz band. The next section of this report will address the feasibility of moving the satellite uplinks for this number of satellites into the 2025 - 2110 MHz band. It is recognized that moving the uplinks of these existing satellites to another frequency band would not be possible, but this gives a good indication of the expected additional satellites that would be in the higher frequency band using this relocation. It is noted that the current band plan in the 1761 - 1843 MHz band is for 20 discrete frequencies and each channel is 4.004 MHz wide.

6 Assessment of the Applicability and Feasibility of Using the Band 2025 - 2110 MHz for Government Satellite Uplink Operations

In reviewing the allocations in the bands 2025 -2110 MHz and comparing them to the Government satellite uplink operations in the 1761 - 1843 MHz band, the satellite operations would clearly fall under the allocation to the space operation service (Earth-to-space). Thus, no further allocation would be necessary either internationally or domestically in order to relocate these satellite uplink operations to the 2025 - 2110 MHz band.

Based on the results from the search of the SRS given in Section 5, it should be noted that there are currently several non-geostationary satellite uplinks and geostationary satellite uplinks operating compatibly in the band 2025 - 2110.

Generally, space operations uplinks (TT&C) are inherently robust by frequency separation due to only narrow-band transmissions, time separation as telecommand information is not sent continuously but are only sporadically, and each satellite has a Unique Code Word for its telecommand so that it will not respond to any signal (such as interference). In the event that co-frequency interference occurs and prevents a telecommand from being successfully received by a satellite, that same telecommand will automatically be transmitted after a delay, by which time the interference may have disappeared.

The following sections assess the feasibility of relocation of these uplink operations with respect to compatible operation with the other services and systems using the band.

6.1 Feasibility of Using the Band 2025 - 2110 MHz for Government Satellite Uplink Operations with Respect to the Satellite Operations Already in the Band

6.1.1 Compatibility between Geostationary Satellite Uplinks

Relocating government satellite uplinks to the 2025 - 2110 MHz band will require that the future satellite systems be coordinated with existing systems and systems filed at the ITU prior to the filing of these future government systems. As there are at least 136 geostationary satellites filed at the ITU with uplinks in this frequency band, it may appear that the addition of approximately 120 geostationary satellites (assuming that the number of satellites in the future will be the same as the number of satellites that currently operate in the 1755 - 1850 MHz band) could make it difficult to accommodate/coordinate all of the satellites.

For sharing between two geostationary satellite uplinks, there are two main methods to reduce the interference into the victim geostationary satellite: one way is to ensure that there is enough orbital separation between the two geostationary satellites so that the earth station antenna off-axis gain discrimination is sufficient to ensure protection of the victim geostationary satellite and the other is to ensure that there is no frequency overlap between the two systems if they are close enough for interference to occur.

In order to get a better idea of the potential difficulty in coordinating the uplinks of geostationary satellite systems in this frequency band, some sample calculations were done using the information for geostationary satellites from the DoD interim report and data gathered from the SRS for other geostationary satellite uplinks. This analysis, which is given in Annex 3, uses these parameters to calculate the net link margins in the presence of interference assuming that two geostationary satellites are separated by 4°. The results of the analysis show that the net margins will be at least 6 dB in all cases investigated.

For those cases where the orbital separation between two geostationary satellites is less than 4°, further analysis is necessary using the expected operational parameters of both systems involved to determine if the orbital separation is sufficient to protect the uplink operations. In the case that the orbital separation is not sufficient, it would be necessary to operate these uplinks on a different frequency. The data from the SRS shows that, for a given orbital location, a very small percentage of the total frequency available in the 2025 - 2110 MHz band is planned for use. Given the amount of spectrum that is available at most orbital locations and the small bandwidths that would be used for the government geostationary satellites, it should not be very difficult to select an uplink frequency that does not overlap the frequencies used by the neighboring satellites.

6.1.2 Compatibility between Non-Geostationary and Geostationary Satellites

With respect to compatibility between existing and planned satellites and relocated Government satellites in the band 2025 - 2110 MHz when one of them is non-geostationary and the other is geostationary, the worst-case interference will occur when the non-geostationary is located directly in-line with the geostationary satellite uplink. (i.e., the non-geostationary satellite is located directly in the path between the geostationary satellite earth station and the geostationary satellite). For this case, it is important to recognize that even if interference is received in the in-line case that degrades the uplink, since one of the satellites is in motion, the impact of this interference may be negligible as the interference events are expected to be infrequency and short in duration.

6.1.2.1 Victim Satellite is the Geostationary Satellite

In order to assess the potential interference from Government non-geostationary satellite uplinks into geostationary satellite uplinks, the parameters for these systems given in the DoD interim report and the SRS were used to analyze the potential interference. This analysis is given in Annex 4. The net link margin of the geostationary satellite uplink in the presence of interference from a Government non-geostationary satellite uplink is calculated for a given interfering earth station off-axis angle. Simulations are then performed to investigate the statistics of the geostationary satellite being located within a certain angle relative to the boresight of the earth station antenna that is tracking the non-geostationary satellite.

The results of the analysis in Annex 4 show that, for an interfering earth station off-axis angle of 2°, the geostationary satellite uplink net link margin will always be greater than 3.4 dB. The simulations that were performed show that the events when the off-axis angle is less than 2° occur infrequently and are short in duration.

6.1.2.2 Victim Satellite is the Non-Geostationary Satellite

The parameters from the DoD interim report and the SRS are used to address the potential interference from the uplinks to geostationary satellites into the uplinks to Government non-geostationary satellites. Annex 5 gives the analysis of interference from geostationary satellite uplinks into non-geostationary satellite uplinks. The analysis first calculates the net margin in the presence of interference assuming a given interfering earth station off-axis angle. Simulations are then performed to investigate the statistics of the non-geostationary satellite being located within a certain angle relative to the boresight of the earth station antenna that is communicating with the geostationary satellite.

The results of the analysis in Annex 5 show that a reasonable off-axis angle for the interfering earth stations will result in net link margins for the non-geostationary satellite uplinks that are positive. These off-axis angles range from 2° to 10° depending on the orbital altitude of the non-geostationary satellite. The simulations that were performed show that the events in which the off-axis angle will be smaller than these values are infrequent and short in duration.

6.1.3 Compatibility between Non-Geostationary Satellites

For the case of the uplink to one non-geostationary satellite interfering with the uplink of another non-geostationary satellite, the parameters given in the DoD interim report are used to analyze the potential interference. The analysis, given in Annex 6, first calculates the net margin in the presence of interference assuming a given interfering earth station off-axis angle. Simulations are then performed to investigate the statistics of the victim non-geostationary satellite being located within a certain angle relative to the boresight of the interfering earth station antenna that is tracking the other non-geostationary satellite. The results of the analysis show that the off-axis angle of the interfering earth station may have to be up to 24°, but could be as small as 3°, in order to ensure that the interference caused by a non-geostationary satellite uplink does not degrade the link margin of the other non-geostationary satellite uplink significantly. The simulations that were performed showed that the duration of these interference events are short in nature.

In this case, it is particularly important to note that the TT&C uplinks are not sent continuously, but only sporadically, and that the same telecommand is expected to be resent automatically after a delay and the interference may have disappeared by the time of this retransmission. Even for those occurrences where the interference degrades the net link margin, it is not expected that this interference would cause significant problems.

One other consideration in the case of two non-geostationary satellites in low- or medium-earth orbits is that the amount of the surface of the earth that the satellite can see at any given time is small. Using earth station diversity (i.e., the uplink earth station for one non-geostationary satellite is separated geographically from the uplink earth station for another non-geostationary satellite), it may be possible to either further mitigate the interference or eliminate it altogether.

6.1.4 Compatibility between GOES Uplinks and Relocated Satellite Uplinks

The interference between Government geostationary satellite uplinks and GOES satellite uplinks is addressed in Annex 7. The analysis is the same as performed in Annex 3 for two geostationary satellites. The results of the analysis show that the net link margin for the Government geostationary satellite uplinks in the presence of interference from a GOES satellite uplink will be greater than 2.7 dB when the two satellites are separated by 4°. The net link margin for the GOES satellite uplinks in the presence of interference from a Government geostationary satellite uplink will be greater than 11.5 dB when the two satellites are separated by 4°. It should be noted that there are very few GOES satellites and they only operate in the lower 10 MHz of the 2025 - 2110 MHz band.

For interference into the GOES satellite uplinks from Government non-geostationary satellite uplinks, the results of the analysis performed in Annex 4 can be applied. For interference from the GOES satellite uplinks into Government non-geostationary satellite uplinks, the results of the analysis performed in Annex 5 can be applied.

6.1.5 Compatibility between Space-to-space operations and Relocated Satellite Uplinks

The same analyses used in the previous sections can be applied to the case of interference between Government satellite uplinks and space-to-space links. In the case of interference into these links, the interfering satellite antenna will be directed toward another satellite and it is expected that there would be some off-axis antenna gain discrimination (since the interference would enter into the far backlobe) or shielding by the spacecraft that would reduce the levels of interference that were received by the satellite. For interference from these links, the same would apply. It is expected that there would be sufficient off-axis gain discrimination from the transmitting satellite antenna relative to the Government satellite receiving antenna. These off-axis gain discriminations or shielding are expected to result in less interference than in the cases addressed in the previous sections. Thus, it is expected that there should be no interference problems for this case.

6.1.6 Deployable/Transportable Earth Stations and Ship Earth Stations

The above sections addressed the case of fixed earth stations for the satellite uplinks in which the earth stations for the victim and interfering satellite uplinks were co-located. For both of these cases, the analysis and conclusions derived above would apply.

6.2 Feasibility of Using the Band 2025 - 2110 MHz for Government Satellite Uplink Operations with Respect to the Fixed and Mobile Systems Already in the Band

With respect to the compatible operation of Government satellite uplinks with the fixed and mobile services in the band 2025 - 2110 MHz, it is important to note that these services have operated compatibly on a co-primary basis in this band for years. No interference problems should be expected for the Government satellite uplinks and there should be no additional interference to the fixed and mobile systems. In fact, this band may be better suited for the Government satellite with respect to interference from mobile systems because the Radio Regulations do not allow the introduction of high-density mobile service systems in this band.

6.3 Feasibility of Using the Band 2025 - 2110 MHz for Government Satellite Uplink Operations with Respect to the Television Services in the United States

As noted in Section 3, the use of the band 2025 - 2110 MHz by the Government space operation service (Earth-to-space) shall not constrain the deployment of the Television Broadcast Auxiliary Service, the Cable Television Relay Service, or the Local Television Transmission Service. Coordination between the non-Government terrestrial receiving stations at fixed sites and the Government Earth station transmitters is required.

The FCC's Memorandum Opinion and Order and Third Notice of Proposed Rule Making and Order (adopted November 19, 1998) regarding the amendment to Section 2.106 of the Commission's Rules to allocate spectrum at 2 GHz for use by the mobile-satellite service states in paragraph 34 "Broadcast Auxiliary Service and Government satellite systems have successfully shared this band for over 30 years."

It is expected that coordination with these systems may need to be performed in the event that a transmitting earth station is located near the fixed sites that are being used.

7 Assessment of Relative Costs Associated with Relocating the Government Satellite Uplink Operations to the Band 2025 - 2110 MHz

The majority of the costs associated with relocating the Government satellite uplink operations from the band 1761 - 1843 MHz to the band 2025 - 2110 MHz will be with respect to the redesign or new construction of earth stations. For future satellites, including those that are planned, but have yet to be designed and construction has not started, it is expected that there would be essentially no difference in costs between using the lower and the higher frequency bands. There may be some time delay associated with using the higher frequency band for future satellites due to the need to develop and space-test the hardware that would be used on the satellites. This may impact satellites expected to be launched in the next few years, but should not cause any delays for satellites that are planned for launch two or three years from now.

For the satellites that are already in orbit or in the construction phase (past the point where frequency can be changed), there would be no possibility of moving the uplink operations with these satellites to the higher frequency band. For these systems, it may be possible to use some type of phasing plan in order to free up some of the spectrum for IMT-2000 systems. The DoD interim report notes that in some instances, satellite programs are supported via two channels in the 1761 - 1843 MHz band. This could possibly open up a portion of the spectrum for IMT-2000 systems in this band.

8 Assessment of Feasibility of Relocating the Earth Station Sites while still Using the Band 1755 - 1850 MHz for Government Satellite Uplink Operations

In other studies, it is being shown that the real interference issue between Government satellite uplinks and IMT-2000 systems is the interference into the IMT-2000 systems. A possible solution to this interference issue is the relocation of the Government satellite uplink earth stations to more remote areas in which IMT-2000 systems would not be as numerous. This needs further investigation to determine the impact on the satellite uplink operations.

9 Summary and Conclusions

This report has analyzed the feasibility of relocating the Federal Government uplink satellite control systems from the 1755 - 1850 MHz band to the 2025 - 2110 MHz band. The report has analyzed the compatibility of the uplink satellite control systems with the other systems that operate in the band 2025 - 2110 MHz. The systems operating in this band include: space operations (Earth-to-space) (space-to-space), Earth exploration-satellite (Earth-to-space) (space-to-space), space research (Earth-to-space) (space-to-space), fixed, and mobile services. Additionally, in the US, the Television Broadcast Auxiliary Service, the Cable Television Relay Service and the Local Television Transmission Service also operate in this band.

This report has analyzed the ability of the Government satellite uplinks to co-exist with the other satellite operations in the band. The analysis has addressed the potential interference between geostationary satellite uplinks, between non-geostationary and geostationary satellite uplinks, and between non-geostationary satellite uplinks. In the case of geostationary satellite uplinks, the analysis has shown that orbital separations of 4° are sufficient to protect the uplinks of both the existing and planned systems and the Government systems. In the case that the satellites are located closer than this and frequency separation is necessary, a search of the international filings for geostationary satellite systems has shown that the frequency usage in the band is very low. At any given orbital location, the majority of the band is unused. It has thus been concluded that coordination of the Government geostationary satellites with other geostationary satellites should not prove to be difficult.

In the case of geostationary satellite uplinks and non-geostationary satellite uplinks operating in this band, the analysis has shown that, although there is the potential to degrade the link margins of the systems, the events will be infrequent and short in duration and the systems should be able to share without putting a burden on either system. In the case of non-geostationary satellites operating with other non-geostationary satellites in the band, the conclusion reached here is that there is the potential for interference between any two systems, but the events will be infrequent and short in duration and there should be no significant problems.

With respect to the Government satellite uplinks operating with the fixed and mobile services worldwide and the Television Broadcast services within the US, it is expected that there may be some coordination that is necessary to ensure the compatible operations of these systems. However, it should be noted that these types of satellite uplinks have existed in this band and operated compatibly with these systems for many years. Thus, it is expected that these systems should be able to operate together without any significant problems.

Annex 1
Results of Search of SRS for Geostationary Satellites using the 2025 - 2110 MHz Band for Uplinks

Table A1-1. Geostationary satellites using the 2025 - 2110 MHz band

Satellite Name	Admin	Orbital Longitude (deg)	Low Frequency (MHz)	High Frequency (MHz)	Total Bandwidth Filed (MHz)	Percentage of Total Available (%)
TDRS 174W	USA	-174	2035.21	2036.71	1.5	1.76
TDRS WEST	USA	-171	2035.21	2036.71	1.5	1.76
DRTS-E	J	-170	2089.737	2090.263	0.526	0.62
GOES WEST	USA	-135	2025.5	2035.0125	9.5125	11.19
GOES WEST-1	USA	-135	2025	2035	10.0	11.76
SYRACUSE-3A	F	-125	2053.31	2055.82	2.51	2.95
TDRS CENTRAL	USA	-79	2035.21	2036.71	1.5	1.76
TDRS-C2	USA	-79	2035.21	2036.71	1.5	1.76
GOES EAST	USA	-75	2025.5	2035.0125	9.5125	11.19
GOES-EAST-1	USA	-75	2025	2035.0125	10.0125	11.78
TDRS 62W	USA	-62	2035.21	2036.71	1.5	1.76
TDRS 49W	USA	-49	2035.21	2036.71	1.5	1.76
SYRACUSE-3B	F	-48	2053.31	2055.82	2.51	2.95
TDRS 46W	USA	-46	2035.21	2036.71	1.5	1.76
ATDRS 41W	USA	-41	2035.21	2036.71	1.5	1.76
TDRS EAST	USA	-41	2035.21	2036.71	1.5	1.76
GENESIS-4	D	-37	2027.5	2107.5	80	94.12
HISPASAT-1	E	-31	2051.7	2052.3	0.6	0.71
HISPASAT-1	E	-31	2057.7625	2058.3625	0.6	0.71
HISPASAT-1	E	-31	2059.7	2060.3	0.6	0.71
HISPASAT-1	E	-31	2072.4958	2073.0958	0.6	0.71
HISPASAT-1	E	-31	2081.95	2082.55	0.6	0.71
HISPASAT-1	E	-31	2083.45	2084.05	0.6	0.71
GENESIS-1	D	-28	2027.5	2107.5	80	94.12
L-SAT	I	-19	2026.4542	2027.0542	0.6	0.71
TV-SAT 2	D	-19	2027.057	2028.002	0.945	1.11
TDF-1	F	-19	2033.3	2033.6	0.3	0.35
TDF-2	F	-19	2036.6	2037.2	0.6	0.71
EUTELSAT 3-14.8W	F/EUT	-14.8	2085.192	2090.96	5.768	6.79
GOMS-1M	RUS	-14.5	2096	2110	14	16.47
EUTELSAT 3-12.5W	F/EUT	-12.5	2085.192	2090.96	5.768	6.79
HIPPARCOS	F/ESA	-12	2063.34	2063.84	0.5	0.59
F-SAT 2	F	-11	2034.35	2034.65	0.3	0.35
MSG-S2	F/ESA	-10	2067.2313	2070.9938	3.7625	4.43
METEOSAT S2	F/ESA	-10	2098.65	2099.35	0.7	0.82
TELECOM-1A	F	-8	2029.416	2032.618	3.202	3.77
TELECOM-2A	F	-8	2029.486	2037.65	8.164	9.60
VIDEOSAT-6	F	-8	2034.95	2038.71	3.76	4.42
SYRACUSE-3C	F	-8	2053.31	2055.82	2.51	2.95
VIDEOSAT-5	F	-7	2034.95	2038.71	3.76	4.42
SYRACUSE-3D	F	-7	2053.31	2055.82	2.51	2.95
SYRACUSE-3E	F	-5	2053.31	2055.82	2.51	2.95
TELECOM-1B	F	-5	2029.416	2032.618	3.202	3.77

Satellite Name	**Admin**	**Orbital Longitude (deg)**	**Low Frequency (MHz)**	**High Frequency (MHz)**	**Total Bandwidth Filed (MHz)**	**Percentage of Total Available (%)**
TELECOM-2B	F	-5	2029.486	2037.65	8.164	9.60
VIDEOSAT-7	F	-5	2034.95	2038.71	3.76	4.42
METEOSAT	F/ESA	0	2097.9715	2106.63	8.6585	10.19
MSG	F/ESA	0	2067.2313	2070.9938	3.7625	4.43
MSG	F/ESA	0	2099.5	2107.65	8.15	9.59
SYRACUSE-3F	F	3	2053.31	2055.82	2.51	2.95
TELECOM-1C	F	3	2029.416	2032.618	3.202	3.77
TELECOM-2C	F	3	2029.486	2037.65	8.164	9.60
EUTELSAT 2-4E	F/EUT	4	2085.192	2090.787	5.595	6.58
EUTELSAT 3-4E	F/EUT	4	2085.192	2090.96	5.768	6.79
SIRIUS-2	S	4.8	2034.026	2034.226	0.2	0.24
MALTASAT-1C	MLT	4.8	2034.541	2043.368	8.827	10.38
MALTASAT-1C	MLT	4.8	2099.921	2107.366	7.445	8.76
EUROSKYWAY-5E	I	5	2029.7	2030.3	0.6	0.71
TELE-X	S/NOT	5	2033.63	2034.07	0.44	0.52
MALTASAT-1A	MLT	6.8	2034.541	2043.368	8.827	10.38
MALTASAT-1A	MLT	6.8	2099.921	2107.366	7.445	8.76
EUTELSAT 2-7E	F/EUT	7	2085.192	2090.787	5.595	6.58
EUTELSAT 3-7E	F/EUT	7	2085.192	2090.96	5.768	6.79
EUTELSAT 2-10E	F/EUT	10	2085.192	2090.787	5.595	6.58
EUTELSAT 3-10E	F/EUT	10	2085.192	2090.96	5.768	6.79
METEOSAT S1	F/ESA	10	2098.65	2099.35	0.7	0.82
MSG-S1	F/ESA	10	2067.2313	2070.9938	3.7625	4.43
ITALSAT-10.2E	I	10.2	2027.7	2028.3	0.6	0.71
EUROSKYWAY-10.2E	I	10.2	2029.7	2030.3	0.6	0.71
EUTELSAT 2-13E	F/EUT	13	2085.192	2090.96	5.768	6.79
EUTELSAT 3-13E	F/EUT	13	2085.192	2090.96	5.768	6.79
GENESIS-5	D	13	2027.5	2107.5	80	94.12
ITALSAT	I	13	2027.7	2028.3	0.6	0.71
ITALSAT-13.2E	I	13.2	2027.7	2028.3	0.6	0.71
EUROSKYWAY-13.2E	I	13.2	2029.7	2030.3	0.6	0.71
MALTASAT-1B	MLT	15.5	2034.541	2043.368	8.827	10.38
MALTASAT-1B	MLT	15.5	2099.921	2107.366	7.445	8.76
EUTELSAT 2-16E	F/EUT	16	2085.192	2090.787	5.595	6.58
EUTELSAT 3-16E	F/EUT	16	2085.192	2090.96	5.768	6.79
SICRAL-2A	I	16.2	2028.7	2030.3	1.6	1.88
ARTEMIS-16.4E-DR	F/ESA	16.4	2026.504	2027.004	0.5	0.59
ITALSAT-16.4E	I	16.4	2027.7	2028.3	0.6	0.71
EUROSKYWAY-16.4E	I	16.4	2029.7	2030.3	0.6	0.71
GENESIS-2	D	18	2027.5	2107.5	80	94.12
ARTEMIS-21.5E-DR	F/ESA	21.5	2026.504	2027.004	0.5	0.59
EUTELSAT 2-21.5E	F/EUT	21.5	2085.192	2090.787	5.595	6.58
EUTELSAT 3-21.5E	F/EUT	21.5	2085.192	2090.96	5.768	6.79

Satellite Name	Admin	Orbital Longitude (deg)	Low Frequency (MHz)	High Frequency (MHz)	Total Bandwidth Filed (MHz)	Percentage of Total Available (%)
SICRAL-2B	I	21.8	2028.7	2030.3	1.6	1.88
EUROSKYWAY-22E	I	22	2029.7	2030.3	0.6	0.71
MALTASAT-1D	MLT	22	2034.541	2043.368	8.827	10.38
MALTASAT-1D	MLT	22	2099.921	2107.366	7.445	8.76
DFS-1	D	23.5	2027.007	2028.498	1.491	1.75
SYRACUSE-3G	F	25	2053.31	2055.82	2.51	2.95
EUTELSAT 3-25.5E	F/EUT	25.5	2085.192	2090.96	5.768	6.79
DFS-2	D	28.5	2027.007	2028.498	1.491	1.75
EUROSKYWAY-30E	I	30	2029.7	2030.3	0.6	0.71
VIDEOSAT-4	F	32	2034.95	2035.25	0.3	0.35
EUTELSAT 2-33E	F/EUT	33	2085.192	2090.787	5.595	6.58
EUTELSAT 3-33E	F/EUT	33	2085.192	2090.96	5.768	6.79
DFS-5	D	33.5	2027.007	2028.498	1.491	1.75
EUTELSAT 2-36E	F/EUT	36	2085.192	2090.787	5.595	6.58
EUTELSAT 3-36E	F/EUT	36	2085.192	2090.96	5.768	6.79
EUROSKYWAY-39E	I	39	2029.7	2030.3	0.6	0.71
EUTELSAT 3-44E	F/EUT	44	2085.192	2090.96	5.768	6.79
EUTELSAT-E-44E	F/EUT	44	2085.192	2090.787	5.595	6.58
SYRACUSE-3H	F	47	2053.31	2055.82	2.51	2.95
EUTELSAT 3-48E	F/EUT	48	2085.192	2090.96	5.768	6.79
EUTELSAT-E-48E	F/EUT	48	2085.192	2090.787	5.595	6.58
GENESIS-6	D	63	2027.5	2107.5	80	94.12
GENESIS-3	D	67	2027.5	2107.5	80	94.12
EUTELSAT 3-70.5E	F/EUT	70.5	2085.192	2090.96	5.768	6.79
EUTELSAT-E-70.5E	F/EUT	70.5	2085.192	2090.787	5.595	6.58
EUTELSAT 3-76E	F/EUT	76	2085.192	2090.96	5.768	6.79
GOMS-M	RUS	76	2096	2110	14	16.47
CHINASAT-41	CHN	80	2030.95	2036.95	6	7.06
EUTELSAT 3-80.5E	F/EUT	80.5	2085.192	2090.96	5.768	6.79
EUTELSAT 3-83.5E	F/EUT	83.5	2085.192	2090.96	5.768	6.79
TDRS 85E	USA	85	2035.21	2036.71	1.5	1.76
CHINASAT-42	CHN	87.5	2030.95	2036.95	6	7.06
EUTELSAT 3-88.5E	F/EUT	88.5	2085.192	2090.96	5.768	6.79
DRTS-W	J	90	2089.737	2090.263	0.526	0.62
CHINASAT-43	CHN	94.5	2030.95	2036.95	6	7.06
CHINASAT-44	CHN	98	2030.95	2036.95	6	7.06
CHINASAT-45	CHN	101.5	2030.95	2036.95	6	7.06
CHINASAT-46	CHN	105	2030.95	2036.95	6	7.06
FY-2A	CHN	105	2044	2059.513	15.513	18.25
SYRACUSE-3I	F	108	2053.31	2055.82	2.51	2.95
TAIKI-109.65	J	109.65	2093.26	2100.36	7.1	8.35
BS-3	J	110	2093.26	2100.36	7.1	8.35

Satellite Name	Admin	Orbital Longitude (deg)	Low Frequency (MHz)	High Frequency (MHz)	Total Bandwidth Filed (MHz)	Percentage of Total Available (%)
DRTS-113E	J	113	2089.737	2090.263	0.526	0.62
CHINASAT-47	CHN	115.5	2030.95	2036.95	6	7.06
GMS-120E	J	120	2025.5	2034.977	9.477	11.15
GMS-120E	J	120	2099.96	2100.36	0.4	0.47
COMETS	J	121	2089.737	2090.263	0.526	0.62
ETS-8-129E	J	129	2025	2110	85	100.00
ETS-8-135E	J	135	2025	2110	85	100.00
MTSAT-135E	J	135	2025.5	2034.977	9.477	11.15
MTSAT-135E	J	135	2099.8465	2100.4815	0.635	0.75
CS-3B	J	136	2096.23	2097.23	1	1.18
GMS-140E	J	140	2025.459	2035.018	9.559	11.25
GMS-140E	J	140	2099.9175	2100.4025	0.485	0.57
GMS-4	J	140	2025.5	2034.977	9.477	11.15
GMS-4	J	140	2099.96	2100.36	0.4	0.47
MTSAT-140E	J	140	2025.5	2034.977	9.477	11.15
MTSAT-140E	J	140	2099.8465	2100.4815	0.635	0.75
MTSAT-145E	J	145	2025.5	2034.977	9.477	11.15
MTSAT-145E	J	145	2099.8465	2100.4815	0.635	0.75
ETS-8-146E	J	146	2025	2110	85	100.00
ETS-5	J	150	2100.01	2100.31	0.3	0.35
CS-3B	J	153.8	2096.23	2097.23	1	1.18
DRTS-160E	J	160	2089.737	2090.263	0.526	0.62
GMS-160E	J	160	2025	2035.0175	10.0175	11.79
GOMS-2M	RUS	166	2096	2110	14	16.47
DRTS-177E	J	177.5	2089.737	2090.263	0.526	0.62

Annex 2

Results of Search of SRS for Non-Geostationary Satellites using the 2025 - 2110 MHz Band for Uplinks

Table A2-1. Non-geostationary satellites using the 2025 - 2110 MHz band

Satellite Name	Adm.	Inclination Angle (°)	Apogee (km)	Perigee (km)	Low Frequency (MHz)	High Frequency (MHz)	Total Bandwidth Filed (MHz)	Percentage of Total Available (%)
QUIKSCAT	USA	98.3	803	803	2025.813	2025.853	0.04	0.05
MLMS	BEL	81.3	835	835	2025.905	2025.945	0.04	0.05
PSLV	IND	90	904	904	2027.85	2029.35	1.5	1.76
SACI	B	98.5	750	750	2028.74	2028.86	0.12	0.14
ETS-7	J	35	550	550	2029.13	2059.37	30.24	35.58
SPOT-1	F	98.7	822	822	2030.994	2031.594	0.6	0.71
SPOT-2	F	81.3	822	822	2031.546	2032.146	0.6	0.71
MECB-S1	B	25	750	750	2032.9	2033.5	0.6	0.71
ETS-7	J	35	550	550	2034.13	2054.37	20.24	23.81
PSLV	IND	90	904	904	2035.21	2036.71	1.5	1.76
ASLV	USA	46	414	394	2035.763	2036.163	0.4	0.47
TOPEX/POSEIDON	USA	66	1336	1336	2036.205	2036.295	0.09	0.11
CASSINI	USA	0	0	0	2038	2042	4	4.71
SPACE SHUTTLE	USA	57	300	300	2038.447	2045.447	7	8.24
SPACE SHUTTLE	USA	57	300	300	2038.947	2044.947	6	7.06
FAST	USA	83	4200	350	2039.628	2039.664	0.036	0.04
TRACE	USA	82	600	600	2039.628	2039.664	0.036	0.04
WIRE	USA	83	540	470	2039.628	2039.664	0.036	0.04
NMP/EO-1	USA	98.2	705	705	2039.628	2039.664	0.036	0.04
SWAS	USA	65	600	600	2039.628	2039.664	0.036	0.04
SAMPEX	USA	82	580	580	2039.632	2039.668	0.036	0.04
PROTEUS-TPFO	F	66	1336	1336	2040.343	2040.643	0.3	0.35
USASAT-30B	USA	82	680	680	2041.903	2042.097	0.194	0.23
JERS-1	J	98	568	568	2043.5	2045	1.5	1.76
MOS-1B	J	99	909	909	2043.5	2045	1.5	1.76
ETS-7	J	35	550	550	2043.58	2044.92	1.34	1.58
MINISAT-1	E	29	585	566	2046.718	2047.318	0.6	0.71
XMM	F/ESA	70	114	7000	2048.354	2049.354	1	1.18
ERS-1	F/ESA	98.5	785	766	2048.6	2049.1	0.5	0.59
BADR-B	PAK	80.4	1000	1000	2049.476	2054.476	5	5.88
USASAT-30B	USA	82	680	680	2051.903	2052.097	0.194	0.23
RADARSAT-1A	CAN	81.4	789	789	2052	2055	3	3.53
EURECA	F/ESA	28.5	525	525	2053.208	2053.708	0.5	0.59
BADR-B	PAK	80.4	1000	1000	2054.476	2059.476	5	5.88
BADR-B	PAK	80.4	1000	1000	2059.476	2060.476	1	1.18
BADR-B	PAK	80.4	1000	1000	2059.476	2064.476	5	5.88
BADR-B	PAK	80.4	1000	1000	2060.476	2061.476	1	1.18
GONETS	RUS	82.5	1500	1500	2060.5	2062.5	2	2.35
SPOT-3	F	98.7	822	822	2061.08	2061.48	0.4	0.47
BADR-B	PAK	80.4	1000	1000	2061.476	2062.476	1	1.18

Satellite Name	Adm.	Inclination Angle (°)	Apogee (km)	Perigee (km)	Low Frequency (MHz)	High Frequency (MHz)	Total Bandwidth Filed (MHz)	Percentage of Total Available (%)
BADR-B	PAK	80.4	1000	1000	2062.476	2063.476	1	1.18
CLUSTER 1-5	F/ESA	90	19134	11863	2063.258	2065.758	2.5	2.94
BADR-B	PAK	80.4	1000	1000	2063.476	2064.476	1	1.18
BADR-B	PAK	80.4	1000	1000	2064.476	2069.476	5	5.88
SOHO	F/ESA	0	0	0	2065.971	2068.571	2.6	3.06
SAX	I	5	600	600	2067.26	2067.74	0.48	0.56
SROSS-1	IND	45.6	408	392	2067.647	2068.147	0.5	0.59
SROSS-3	IND	45.6	401	385	2067.647	2068.147	0.5	0.59
BADR-B	PAK	80.4	1000	1000	2069.476	2074.476	5	5.88
CLUSTER 1-5	F/ESA	90	19134	11863	2069.704	2072.204	2.5	2.94
FUSE	USA	25	775	775	2070.936	2070.972	0.036	0.04
IRS-1B	IND	99	919	890	2071.625	2072.125	0.5	0.59
AXAF-1	USA	28.5	140	10	2071.857	2071.893	0.036	0.04
TRMM	USA	35	350	350	2073.92	2079.96	6.04	7.11
WAKE SHIELD FACILITY	USA	28.5	300	300	2074.4	2075.6	1.2	1.41
BADR-B	PAK	80.4	1000	1000	2074.476	2079.476	5	5.88
COMET	USA	40	556	556	2074.97	2075.031	0.061	0.07
CLUSTER 1-5	F/ESA	90	19134	11863	2076.15	2078.65	2.5	2.94
ASTRO-D	J	31	550	550	2077.287	2077.913	0.626	0.74
SOLAR-A	J	31	600	600	2077.34	2077.86	0.52	0.61
GEOTAIL	J	7.5	51000	14000	2079.375	2082.625	3.25	3.82
BADR-B	PAK	80.4	1000	1000	2079.476	2084.476	5	5.88
GEOTAIL	J	7.5	51000	14000	2079.675	2082.325	2.65	3.12
INTNL SPACE STN ACS	USA	51.6	500	500	2082.688	2088.688	6	7.06
SFU	J	28.5	500	500	2082.744	2086.056	3.312	3.90
MUSES-B	J	31	22000	1000	2083.22	2085.58	2.36	2.78
BADR-B	PAK	80.4	1000	1000	2084.476	2089.476	5	5.88
ISTP POLAR	USA	86	57402	11480	2085.562	2085.818	0.256	0.30
ISO	F/ESA	5.2	70998	990	2086.567	2087.567	1	1.18
CLUSTER 1-5	F/ESA	90	19134	11863	2089.042	2091.542	2.5	2.94
BADR-B	PAK	80.4	1000	1000	2089.476	2094.476	5	5.88
HETE	USA	38	550	550	2092.112	2092.149	0.037	0.04
BADR-B	PAK	80.4	1000	1000	2092.5	2093	0.5	0.59
MICROLAB-1	USA	70	785	785	2092.571	2092.61	0.039	0.05
SEASTAR	USA	98.2	705	705	2092.571	2092.61	0.039	0.05
NIMBUS-7	USA	99	960	945	2092.765	2094.265	1.5	1.76
SNOE	USA	97.6	550	550	2092.942	2092.982	0.04	0.05
TERRIERS	USA	97.6	550	550	2092.944	2092.981	0.037	0.04
BADR-B	PAK	80.4	1000	1000	2093	2093.5	0.5	0.59
TOMS-EP	USA	82.6	500	500	2093.497	2093.533	0.036	0.04
BADR-B	PAK	80.4	1000	1000	2093.5	2094	0.5	0.59
BADR-B	PAK	80.4	1000	1000	2094	2094.5	0.5	0.59
BADR-B	PAK	80.4	1000	1000	2094.476	2099.476	5	5.88
BADR-B	PAK	80.4	1000	1000	2094.5	2095	0.5	0.59

Satellite Name	Adm.	Inclination Angle (°)	Apogee (km)	Perigee (km)	Low Frequency (MHz)	High Frequency (MHz)	Total Bandwidth Filed (MHz)	Percentage of Total Available (%)
ISTP WIND	USA	33	16000	31900	2094.882	2094.918	0.036	0.04
CLUSTER 1-5	F/ESA	90	19134	11863	2095.488	2097.988	2.5	2.94
CASSINI	USA	0	0	0	2095.92	2099.92	4	4.71
ETS-7	J	35	550	550	2096.06	2097.4	1.34	1.58
ACE	USA	23	12	18	2097.465	2098.497	1.032	1.21
MINISAT-1	E	29	585	566	2100.581	2101.181	0.6	0.71
SPACE SHUTTLE	USA	57	300	300	2102.906	2109.906	7	8.24
LANDSAT-7	USA	98.2	705	705	2103.15	2109.65	6.5	7.65
EOS AM	USA	81.8	714	697	2103.4	2109.4	6	7.06
GRO	USA	28.5	350	350	2103.4	2109.4	6	7.06
GRO OMNI	USA	28.5	350	350	2103.4	2109.4	6	7.06
ISS ICM	USA	51.6	350	350	2103.4	2109.4	6	7.06
LANDSAT-4	USA	98.2	705	705	2103.4	2109.4	6	7.06
ST OMNI	USA	28.5	500	500	2103.4	2109.4	6	7.06
XTE	USA	23	600	600	2103.4	2109.4	6	7.06
SPACE SHUTTLE	USA	57	300	300	2103.406	2109.406	6	7.06
EUVE	USA	28.5	550	550	2103.9	2108.9	5	5.88
ISS ECOMM	USA	51.6	350	350	2103.9	2108.9	5	5.88
UARS	USA	57	600	600	2103.9	2108.9	5	5.88
TOPEX/POSEIDON	USA	66	1336	1336	2103.906	2108.906	5	5.88
LANDSAT1-2	USA	81	918	905	2104.6	2108.2	3.6	4.24
ERBS	USA	46	600	600	2105.406	2107.406	2	2.35
LANDSAT-4	USA	98.2	705	705	2105.9	2106.9	1	1.18
LANDSAT-7	USA	98.2	705	705	2106.35	2106.45	0.1	0.12
EOS AM	USA	81.8	714	697	2106.369	2106.431	0.062	0.07
EUVE	USA	28.5	550	550	2106.382	2106.418	0.036	0.04
XTE	USA	23	600	600	2106.382	2106.418	0.036	0.04
TOPEX/POSEIDON	USA	66	1336	1336	2106.388	2106.424	0.036	0.04
EXOS-D	J	75	8000	300	2108.3	2108.82	0.52	0.61

Annex 3
Analysis of Interference between Government Geostationary Satellite Uplinks and Other Geostationary Satellite Uplinks in the Band 2025 - 2110 MHz

A3.1 Introduction

In this annex, the potential interference between existing and planned geostationary satellite uplinks in the bands and relocated Government geostationary satellite uplinks are investigated. The parameters for the relocated Government geostationary satellite uplinks are taken from the DoD interim report. The parameters for the existing and planned geostationary satellite uplinks are taken from the data given in the SRS. Not all of the geostationary satellites contained in the SRS are investigated, but the ones that are investigated are expected to adequately represent the types of systems that will be in the band. The analyses investigate the case where the orbital separation between the two geostationary satellites is 4°.

A3.2 Interference into DoD Geostationary Satellite Uplinks

The analysis of interference into the DoD satellite uplinks is performed using the minimum link parameters given in the DoD interim report. An elevation angle from the earth station to the satellite of 3° and an earth station transmitter power is 2000 watts are assumed. The satellite receive antenna is assumed to be omnidirectional with a gain of -5 dBi in all directions. The carrier power for this uplink is calculated by adding the minimum margin given in the DoD interim report (8.4 dB) and the system noise (-199.58 dBW/Hz, based on a receiver system noise temperature of 798.1K). As the margin is for an uplink operating at 1800 MHz and this analysis is investigating uplinks in the 2025 - 2110 MHz band, the margin is adjusted by the corresponding difference in space loss between the two frequencies. A center frequency of 2050 MHz is chosen in this analysis. This results in an additional 1.13 dB of space loss and the resultant minimum link margin is 7.27 dB.

For the interfering systems, the maximum transmitter power levels that are in the ITU publications are used to determine the interference into the DoD satellite uplinks. For this analysis, it is assumed that the interfering earth station is located directly below the victim geostationary satellite (i.e., at the closest distance). The earth station antenna off-axis gain is calculated using Recommendation ITU-R S.465. The analysis calculates the interfering signal power at the victim geostationary satellite and then calculates the net link margin in the presence of this interference. The results of this analysis are shown in Table A3.2-1. The evaluation presented here is a worst-case analysis and the interference potential during operation is expected to be less than what is shown here.

Table A3.2-1. Results of Analysis of Interference into DoD Geostationary Satellite Uplinks

Interfering Satellite	CHINASAT-41	GENESIS 4	SYRACUSE-3C	EUTELSAT 2-4E
Orbital Longitude	80E	37W	8W	4E
Earth Station Antenna Gain (dBi)	46.5	38.4	44.8	39.5
Max Tx Power (dBW)	28.5	23.6	26.0	23.0
Max EIRP (dBW)	75.0	62.0	70.8	62.5
ES Antenna Off-Axis Angle (°)	4.5	4.5	4.5	4.5
ES Antenna Off-Axis Gain (dB)	15.68	15.68	15.68	15.68
Minimum Distance (km)	35786.0	35786.0	35786.0	35786.0
Frequency (MHz)	2050.0	2050.0	2050.0	2050.0
Space Loss (dB)	189.76	189.76	189.76	189.76
Victim Satellite				
Minimum Margin (dB)	7.27	7.27	7.27	7.27
Noise Power (dBW/Hz)	-199.58	-199.58	-199.58	-199.58
Carrier Signal Power Density (dBW/Hz)	-192.31	-192.31	-192.31	-192.31
Victim Satellite Antenna Gain (dBi)	-5.0	-5.0	-5.0	-5.0
Interfering Signal Power (dBW)	-150.58	-155.48	-153.08	-156.08
Bandwidth of Emission (kHz)	1000	200	300	300
Interfering Signal Power Density (dBW/Hz)	-210.58	-208.49	-207.85	-210.85
I + N (dBW/Hz)	-199.25	-199.05	-198.98	-199.27
Net Link Margin (dB)	6.94	6.75	6.67	6.96

Table A3.2-1 (continued). Results of Analysis of Interference into DoD Geostationary Satellite Uplinks

Interfering Satellite	GMS-140E	GMS-140E	EUROSKYWAY	TDRS / ATDRS
Orbital Longitude	140E	140E	39E	174W/41W
Earth Station Antenna Gain (dBi)	44.9	49.9	43.0	43.4
Max Tx Power (dBW)	17.2	27.1	22.0	28.0
Max EIRP (dBW)	62.1	77.0	65.0	71.4
ES Antenna Off-Axis Angle (°)	4.5	4.5	4.5	4.5
ES Antenna Off-Axis Gain (dB)	15.68	15.68	15.68	15.68
Minimum Distance (km)	35786.0	35786.0	35786.0	35786.0
Frequency (MHz)	2050.0	2050.0	2050.0	2050.0
Space Loss (dB)	189.76	189.76	189.76	189.76
Victim Satellite				
Minimum Margin (dB)	7.27	7.27	7.27	7.27
Noise Power (dBW/Hz)	-199.58	-199.58	-199.58	-199.58
Carrier Signal Power Density (dBW/Hz)	-192.31	-192.31	-192.31	-192.31
Victim Satellite Antenna Gain (dBi)	-5.0	-5.0	-5.0	-5.0
Interfering Signal Power (dBW)	-160.68	-151.98	-157.08	-151.08
Bandwidth of Emission (kHz)	35	2000	600	1500
Interfering Signal Power Density (dBW/Hz)	-206.12	-214.99	-214.86	-212.84
I + N (dBW/Hz)	-198.71	-199.46	-199.45	-199.38
Net Link Margin (dB)	6.4	7.15	7.14	7.07

These results show that the Government geostationary satellite uplink net link margin in the presence of interference from planned or existing geostationary satellite uplinks in the band 2025 - 2110 MHz will be greater than 6 dB when the two satellites are separated by 4°. In those cases where the relocated satellite is located within 4° of an existing satellite, further analysis would be necessary to determine if this orbital separation is sufficient to protect the geostationary satellite uplinks. In the case that orbital separation is not sufficient to protect the uplinks, frequency separation would be necessary to ensure compatible operation. Based on the data in the SRS regarding frequency usage at any given orbital location, it should not be difficult to use frequency separation to achieve coordination in these cases.

A3.3 Interference from DoD Geostationary Satellite Uplinks into Other Geostationary Satellite Uplinks

For the analysis of interference from the DoD geostationary satellite uplinks into the geostationary satellite uplinks for systems in the SRS, the maximum transmitter power for the DoD satellite uplinks is used. The received interfering signal power at the victim satellite is calculated using this power and the earth station antenna off-axis gain. The earth station antenna off-axis gain is determined using the figures given in the DoD interim report. This analysis assumes that the elevation angle from the interfering earth station to the victim satellite is 90°. For the victim systems, the minimum EIRP levels in the SRS are used to determine the carrier signal power assuming a 3° elevation angle from the earth station to the satellite and an omnidirectional receive antenna. The analysis calculates the net link margin in the presence of the interference from the DoD satellite uplink. The results of this analysis are shown in Table A3.3-1. The evaluation presented here is a worst-case analysis and the interference potential during operation is expected to be less than what is shown here.

Table A3.3-1. Results of Analysis of Interference from DoD Geostationary Satellite Uplinks into Other Geostationary Satellite Uplinks

Victim Satellite	CHINASAT-41	GENESIS 4	SYRACUSE-3C	EUTELSAT 2-4E
Orbital Longitude	80E	37W	8W	4E
Earth Station Antenna Gain (dBi)	46.5	38.4	44.8	39.5
Min Tx Power (dBW)	25.5	18.6	26.0	23.0
Min EIRP (dBW)	72.0	57.0	70.8	62.5
Distance @ 3° elevation (km)	41346.4	41346.4	41346.4	41346.4
Frequency (MHz)	2050.0	2050.0	2050.0	2050.0
Space Loss (dB)	191.01	191.01	191.01	191.01
Satellite Antenna Gain (dBi)	0.0	0.0	1.0	0.0
Carrier Signal Power Received (dBW)	-119.01	-134.01	-119.21	-128.51
Rcvr Noise Temperature (K)	750.0	700.0	700.0	1100.0
Bandwidth (kHz)	1000	200	300	300
System Noise Power (dBW)	-139.85	-147.14	-145.38	-143.41
Interfering Satellite				
Earth Station Tx Power (dBW)	38.45	38.45	38.45	38.45
Earth Station Max Gain (dBi)	49.3	49.3	49.3	49.3
Earth Station Max EIRP (dBW)	87.75	87.75	87.75	87.75
Bandwidth of Emission (kHz)	4004	4004	4004	4004
Tx Power in Victim Bandwidth (dBW)	32.43	25.44	27.20	27.2
ES Antenna Off-Axis Angle (°)	4.5	4.5	4.5	4.5
ES Antenna Off-Axis Gain (dBi)	18.0	18.0	18.0	18.0
Minimum Distance (km)	35786.0	35786.0	35786.0	35786.0
Space Loss (dB)	189.76	189.76	189.76	189.76
Victim Satellite Antenna Gain (dBi)	0.0	0.0	1.0	0.0
Interfering Signal Power Received (dBW)	-139.33	-146.32	-143.56	-144.56
I + N (dBW)	-136.57	-143.70	-141.37	-140.94
Net Link Margin (dB)	17.56	9.69	22.15	12.43

Table A3.3-1 (continued). Results of Analysis of Interference from DoD Geostationary Satellite Uplinks into Other Geostationary Satellite Uplinks

Victim Satellite	GMS-140E	GMS-140E	EUROSKYWAY	TDRS/ ATDRS
Orbital Longitude	140E	140E	39E	174W/41W
Earth Station Antenna Gain (dBi)	44.9	49.9	43.0	38.7
Min Tx Power (dBW)	17.2	17.1	21.0	28.0
Min EIRP (dBW)	62.1	67.0	64.0	66.7
Distance @ 3° elevation (km)	41346.4	41346.4	41346.4	41346.4
Frequency (MHz)	2050.0	2050.0	2050.0	2050.0
Space Loss (dB)	191.01	191.01	191.01	191.01
Satellite Antenna Gain (dBi)	19.0	19.0	2.0	0.0
Carrier Signal Power Received (dBW)	-109.91	-105.01	-125.01	-124.31
Rcvr Noise Temperature (K)	1862.0	1862.0	1200.0	2900.0
Bandwidth of Emission (kHz)	35	1000	600	1500
System Noise Power (dBW)	-150.46	-135.90	-140.03	-132.22
Interfering Satellite				
Earth Station Tx Power (dBW)	38.45	38.45	38.45	38.45
Earth Station Max Gain (dBi)	49.3	49.3	49.3	49.3
Earth Station Max EIRP (dBW)	87.75	87.75	87.75	87.75
Bandwidth of Emission (kHz)	4004	4004	4004	4004
Tx Power in Victim Bandwidth (dBW)	17.87	32.43	30.21	34.19
ES Antenna Off-Axis Angle (°)	4.5	4.5	4.5	4.5
ES Antenna Off-Axis Gain (dBi)	18.0	18.0	18.0	18.0
Minimum Distance (km)	35786.0	35786.0	35786.0	35786.0
Space Loss (dB)	189.76	189.76	189.76	189.76
Victim Satellite Antenna Gain (dBi)	19.0	19.0	2.0	0.0
Interfering Signal Power Received (dBW)	-134.89	-120.33	-139.55	-137.57
I + N (dBW)	-134.77	-120.21	-136.77	-131.10
Net Link Margin (dB)	24.86	15.20	11.8	6.86

These results show that the net link margin of an existing or planned geostationary satellite uplink in the presence of interference from a relocated Government geostationary satellite uplink in the band 2025 - 2110 MHz will be greater than 6 dB when the two satellites are separated by 4°. In those cases where the relocated satellite is located within 4° of an existing satellite, further analysis would be necessary to determine if this orbital separation is sufficient to protect the geostationary satellite uplinks. In the case that orbital separation is not sufficient to protect the uplinks, frequency separation would be necessary to ensure compatible operation. Based on the data in the SRS regarding frequency usage at any given orbital location, it should not be difficult to use frequency separation to achieve coordination in these cases.

Annex 4

Analysis of Interference from Government Non-Geostationary Satellite Uplinks into Geostationary Satellite Uplinks in the Band 2025 - 2110 MHz

A4.1 Introduction

In this annex, the potential interference from Government non-geostationary satellite uplinks into geostationary satellite uplinks is analyzed. The parameters given in the DoD interim report for the non-geostationary satellites are used in this analysis. The parameters given in the SRS are used for the geostationary satellite uplinks. The maximum transmitter power and earth station antenna gain for the uplink to the non-geostationary satellite are used. The net link margin of the geostationary satellite uplinks is calculated assuming a 2° interfering earth station off-axis angle toward the geostationary satellites. Simulations are then performed to determine the statistics that the geostationary satellite will be located within 2° of the boresight of the earth station antenna that is tracking the non-geostationary satellite. For this analysis, it is assumed that the geostationary satellite earth station has a 3° elevation angle to the geostationary satellite and the non-geostationary satellite uplink earth station is located directly under the geostationary satellite (i.e., shortest path distance). The results of this analysis are shown in Table A4.1-1.

Table A4.1-1. Results of Analysis of Interference from DoD Non-Geostationary Satellite Uplinks into Geostationary Satellite Uplinks

Victim Satellite Parameters	Chinasat-41	Genesis-4	Syracuse-3C	EUTELSAT 2-4E
Min Tx Power (dBW)	25.5	18.6	26.0	23.0
Earth Station Antenna Gain (dBi)	46.5	38.4	44.8	39.5
Min EIRP (dBW)	72.0	57.0	70.8	62.5
Distance @ 3° elevation (km)	41346.4	41346.4	41346.4	41346.4
Frequency (MHz)	2050	2050	2050	2050
Space Loss (dB)	191.01	191.01	191.01	191.01
Satellite Antenna Gain (dBi)	0.0	0.0	1.0	0.0
Carrier Signal Power Received (dBW)	-119.01	-134.01	-119.21	-128.51
Receiver Noise Temperature (K)	750	700	700	1100
Bandwidth (kHz)	1000	200	300	300
System Noise Power (dBW)	-139.85	-147.14	-145.38	-143.41
Interfering Satellite Parameters				
Earth Station Tx Power (dBW)	38.45	38.45	38.45	38.45
Earth Station Max Gain (dBi)	49.3	49.3	49.3	49.3
Earth Station EIRP (dBW)	87.75	87.75	87.75	87.75
Bandwidth of Emission (kHz)	4004	4004	4004	4004
Tx Power in Victim Bandwidth (dBW)	32.43	25.44	27.20	27.20
ES Antenna Off-Axis Angle (°)	2	2	2	2
ES Antenna Off-Axis Gain (dBi)	26.0	26.0	26.0	26.0
Minimum Distance (km)	35786	35786	35786	35786
Space Loss (dB)	189.76	189.76	189.76	189.76
Interfering Signal Power Received (dBW)	-131.33	-138.32	-135.56	-136.56
I + N (dBW)	-130.76	-137.79	-135.13	-135.75
Net Link Margin (dB)	11.75	3.77	15.92	7.23

Table A4.1-1 (continued). Results of Analysis of Interference from DoD Non-Geostationary Satellite Uplinks into Geostationary Satellite Uplinks

Victim Satellite Parameters	GMS-140E	GMS-140E	EUROSKYWAY	TDRS /ATDRS
Min Tx Power (dBW)	17.2	17.1	21.0	28.0
Earth Station Antenna Gain (dBi)	44.9	49.9	43.0	38.7
Min EIRP (dBW)	62.1	67.0	64.0	66.7
Distance @ 3° elevation (km)	41346.4	41346.4	41346.4	41346.4
Frequency (MHz)	2050	2050	2050	2050
Space Loss (dB)	191.01	191.01	191.01	191.01
Satellite Antenna Gain (dBi)	19.0	19.0	2.0	0.0
Carrier Signal Power Received (dBW)	-109.91	-104.93	-124.93	-124.23
Receiver Noise Temperature (K)	1862	1862	1200	2900
Bandwidth (kHz)	35	1000	600	1500
System Noise Power (dBW)	-150.46	-135.90	-140.03	-132.22
Interfering Satellite Parameters				
Earth Station Tx Power (dBW)	38.45	38.45	38.45	38.45
Earth Station Max Gain (dBi)	49.3	49.3	49.3	49.3
Earth Station EIRP (dBW)	87.75	87.75	87.75	87.75
Bandwidth of Emission (kHz)	4004	4004	4004	4004
Tx Power in Victim Bandwidth (dBW)	17.87	32.43	30.21	34.19
ES Antenna Off-Axis Angle (°)	2	2	2	2
ES Antenna Off-Axis Gain (dBi)	26.0	26.0	26.0	26.0
Minimum Distance (km)	35786	35786	35786	35786
Space Loss (dB)	189.76	189.76	189.76	189.76
Interfering Signal Power Received (dBW)	-126.89	-112.25	-131.47	-129.49
I + N (dBW)	-126.87	-112.23	-130.90	-127.63
Net Link Margin (dB)	16.96	7.30	5.97	3.40

Simulations were run for each of the three orbital altitudes that are given in the DoD interim report and an assumed orbit inclination angle. These altitudes and inclination angles are: 250 km, 56°; 833 km, 98.2°; and 20,200 km, 65°. The simulations were run for 100 days at a time increment of 0.1 seconds. The earth station for the uplink to the non-geostationary satellite was located at 40N, 100W and the geostationary satellite was located at 100W. At each time increment in the simulation, the new position of the non-geostationary satellite is calculated and the pointing angle (azimuth and elevation) from the earth station to the non-geostationary satellite is determined. The off-axis angle between this pointing angle and the pointing angle to the geostationary satellite is then calculated. The total time that the off-axis angle is less than 2° is calculated. The number of events where the off-axis angle was within 2° is also calculated. An event begins the first time the off-axis angle is less than 2° and ends when the off-axis angle is greater than 2°. The longest duration of an event is also determined. Table A4.1-2 gives the results of these simulations for each of the non-geostationary satellite orbits.

Table A4.1-2 Results of Simulations

Orbital Altitude	Number of Events	Percentage of Total Simulation Time	Duration of longest event (minutes)	Duration of longest event (seconds)
250 km	6	0.0002%	0.062	3.7
833 km	12	0.0015%	0.225	13.5
20,200 km	9	0.0367%	7.3	438.2

The results in this annex have shown the geostationary satellite uplink net link margin in the presence of interference from Government non-geostationary satellite uplinks for an interfering earth station off-axis angle of 2° will always be greater than 3.4 dB. Additionally, simulations were performed to determine the statistics of the events in which the earth station antenna off-axis angle is less than 2°. The results of these simulations show that these events will be infrequent and generally short in duration.

Annex 5

Analysis of Interference from Geostationary Satellite Uplinks into Government Non-Geostationary Satellite Uplinks in the Band 2025 - 2110 MHz

A5.1 Introduction

In this annex, the potential interference from geostationary satellite uplinks into Government non-geostationary satellite uplinks is analyzed. The parameters given in the DoD interim report for the non-geostationary satellite uplinks and the parameters given in the SRS for the geostationary satellite uplinks are used. The maximum transmitter power and antenna gain for the geostationary satellite uplink and the minimum parameters for the non-geostationary satellite uplink are used in this analysis to calculate the interference into a DoD non-geostationary satellite uplink assuming an interfering earth station off-axis angle. It is assumed that the non-geostationary satellite earth station has a 3° elevation angle to the non-geostationary satellite and the geostationary satellite uplink earth station is located directly under the non-geostationary satellite (i.e., shortest path distance). The carrier power for the non-geostationary satellite uplinks is calculated by adding the minimum margin given in the DoD interim report and the system noise. As the margin is for an uplink operating at 1800 MHz and this analysis is investigating uplinks in the 2025 - 2110 MHz band, the margin is adjusted by the corresponding difference in space loss between the two frequencies. A center frequency of 2050 MHz is chosen in this analysis, which results in an additional 1.13 dB of space loss. For the geostationary satellite uplinks, the antenna gain pattern given in Recommendation ITU-R S.465 is used to determine the earth station antenna off-axis gain. Simulations are then performed to determine the statistics that the non-geostationary satellite will be located within this off-axis angle of the boresight of the earth station antenna that is pointing at the geostationary satellite. The results of this analysis are shown in Tables A5.1-1, A5.1-2 and A5.1-3 for non-geostationary satellites in orbits of 250 km, 833 km and 20,200 km, respectively. The analysis was performed for each of the geostationary satellite uplinks that are used in Annex 3 of this report, but the results are only shown for the four that resulted in the smallest net link margins for the non-geostationary satellite uplinks.

Table A5.1-1. Results of Analysis of Interference from Geostationary Satellite Uplinks into Non-Geostationary Satellite Uplinks (250 km Orbit)

Interfering Satellite	Chinasat-41	Genesis-4	Syracuse-3C	GMS-140E
Max Tx Power (dBW)	28.5	23.6	26.0	18.4
Earth Station Antenna Gain (dBi)	46.5	38.4	44.8	44.9
Max EIRP (dBW)	75.0	62.0	70.8	63.3
ES Antenna Off-Axis Angle (°)	10	10	10	10
ES Antenna Off-Axis Gain (dBi)	5.74	5.74	5.74	5.74
Minimum Distance (km)	250	250	250	250
Frequency (MHz)	2050.0	2050.0	2050.0	2050.0
Space Loss (dB)	146.64	146.64	146.64	146.64
Victim Satellite Parameters				
Minimum Margin (dB)	28.2	28.2	28.2	28.2
Noise Power (dBW/Hz)	-199.58	-199.58	-199.58	-199.58
Carrier Signal Power Density (dBW/Hz)	-172.51	-172.51	-172.51	-172.51
Victim Satellite Antenna Gain (dBi)	-5	-5	-5	-5
Interfering Signal Power (dBW)	-117.4	-122.3	-119.9	-127.5
Bandwidth of Emission (kHz)	1000	200	300	35
Interfering Signal Power Density (dBW/Hz)	-177.40	-175.31	-174.68	-172.94
I+N (dBW/Hz)	-177.38	-175.30	-174.66	-172.94
Net Link Margin (dB)	4.87	2.79	2.15	0.43

Table A5.1-2. Results of Analysis of Interference from Geostationary Satellite Uplinks into Non-Geostationary Satellite Uplinks (833 km Orbit)

Interfering Satellite	Chinasat-41	Genesis-4	Syracuse-3C	GMS-140E
Max Tx Power (dBW)	28.5	23.6	26.0	18.4
Earth Station Antenna Gain (dBi)	46.5	38.4	44.8	44.9
Max EIRP (dBW)	75.0	62.0	70.8	63.3
ES Antenna Off-Axis Angle (°)	7	7	7	7
ES Antenna Off-Axis Gain (dBi)	9.61	9.61	9.61	9.61
Minimum Distance (km)	833	833	833	833
Frequency (MHz)	2050.0	2050.0	2050.0	2050.0
Space Loss (dB)	157.1	157.1	157.1	157.1
Victim Satellite Parameters				
Minimum Margin (dB)	22.0	22.0	22.0	22.0
Noise Power (dBW/Hz)	-199.58	-199.58	-199.58	-199.58
Carrier Signal Power Density (dBW/Hz)	-178.71	-178.71	-178.71	-178.71
Victim Satellite Antenna Gain (dBi)	-5	-5	-5	-5
Interfering Signal Power (dBW)	-123.99	-128.89	-126.49	-134.09
Bandwidth of Emission (kHz)	1000	200	300	35
Interfering Signal Power Density (dBW/Hz)	-183.99	-181.90	-181.26	-179.53
I+N (dBW/Hz)	-183.87	-181.83	-181.20	-179.49
Net Link Margin (dB)	5.16	3.12	2.49	0.78

Table A5.1-3. Results of Analysis of Interference from Geostationary Satellite Uplinks into Non-Geostationary Satellite Uplinks (20,200 km Orbit)

Interfering Satellite	Chinasat-41	Genesis-4	Syracuse-3C	GMS-140E
Max Tx Power (dBW)	28.5	23.6	26.0	18.4
Earth Station Antenna Gain (dBi)	46.5	38.4	44.8	44.9
Max EIRP (dBW)	75.0	62.0	70.8	63.3
ES Antenna Off-Axis Angle (°)	2	2	2	2
ES Antenna Off-Axis Gain (dBi)	23.21	23.21	23.21	23.21
Minimum Distance (km)	20,200	20,200	20,200	20,200
Frequency (MHz)	2050.0	2050.0	2050.0	2050.0
Space Loss (dB)	184.79	184.79	184.79	184.79
Victim Satellite Parameters				
Minimum Margin (dB)	12.6	12.6	12.6	12.6
Noise Power (dBW/Hz)	-199.58	-199.58	-199.58	-199.58
Carrier Signal Power Density (dBW/Hz)	-188.11	-188.11	-188.11	-188.11
Victim Satellite Antenna Gain (dBi)	-5	-5	-5	-5
Interfering Signal Power (dBW)	-138.09	-142.99	-140.59	-148.19
Bandwidth of Emission (kHz)	1000	200	300	35
Interfering Signal Power Density (dBW/Hz)	-198.09	-196.00	-195.36	-193.63
I+N (dBW/Hz)	-195.76	-194.42	-193.96	-192.64
Net Link Margin (dB)	7.65	6.31	5.86	4.54

Simulations were run for the off-axis angles used in Tables A5.1-1 through A5.1-3 for each of the orbital altitudes to determine the statistics that the non-geostationary satellite would be located within the off-axis angle of the boresight of the earth station antenna communicating with the geostationary satellite. The simulations were run for 100 days at a time increment of 0.1 seconds. The earth station for the uplink to the non-geostationary satellite was located at 40N, 100W and the geostationary satellite was located at 100W. At each time increment in the simulation, the new position of the non-geostationary satellite is calculated and the pointing angle (azimuth and elevation) from the earth station location to the non-geostationary satellite is determined. The off-axis angle between this pointing angle and the pointing angle to the geostationary satellite is then calculated. The total time that the off-axis angle is less than the given angle is calculated. The number of events where the off-axis angle was within this angle is also calculated. An event begins the first time the off-axis angle is less than this angle and ends when the off-axis angle is greater than this angle. The longest duration of an event is also determined. Table A5.1-4 gives the results of these simulations for each of the non-geostationary satellite orbits.

Table A5.1-4 Results of Simulations

Orbital Altitude	Off-Axis Angle	Number of Events	Percentage of Total Simulation Time	Duration of longest event (minutes)	Duration of longest event (seconds)
250 km	10.0	16	0.0033%	0.33	19.8
833 km	7.0	31	0.0149%	0.795	47.7
20,200 km	2.0	9	0.0367%	7.3	438.2

The results of the analyses presented in this annex have shown that, for the geostationary satellite earth station off-axis angles investigated, the net margin of the victim non-geostationary satellite uplink will be positive. Simulations have been performed to determine the probabilities that the off-axis angle would be smaller than the angle used in the analysis. The results of these simulations show that these events will be infrequent and generally short in duration.

Annex 6

Analysis of Interference between Non-Geostationary Satellite Uplinks in the 2025 - 2110 MHz Band

A6.1 Introduction

In this annex, the potential interference from non-geostationary satellite uplinks into other non-geostationary satellite uplinks is analyzed. The parameters given in the DoD interim report for the non-geostationary satellites are used in this analysis. The maximum transmitter power and antenna gain for the interfering non-geostationary satellite uplink and the minimum parameters for the victim non-geostationary satellite uplink are used in this analysis to calculate the interference assuming an interfering earth station off-axis angle. It is assumed that the non-geostationary satellite earth station has a 3° elevation angle to the victim non-geostationary satellite and the interfering non-geostationary satellite uplink earth station is located directly under the victim non-geostationary satellite (i.e., shortest path distance). The carrier power for the non-geostationary satellite uplinks is calculated by adding the minimum margin given in the DoD interim report and the system noise. As the margin is for an uplink operating at 1800 MHz and this analysis is investigating uplinks in the 2025 - 2110 MHz band, the margin is adjusted by the corresponding difference in space loss between the two frequencies. A center frequency of 2050 MHz is chosen in this analysis, which results in an additional 1.13 dB of space loss. The resultant net link margin is calculated. Simulations are then performed to determine the statistics that the victim non-geostationary satellite will be located within this angle of the boresight of the earth station antenna that is tracking the interfering non-geostationary satellite. The results of this analysis are shown in Tables A6.1-1. As the maximum transmitter powers of each of the non-geostationary satellite uplinks are the same, the interference to a non-geostationary satellite uplink at a given altitude will be the same regardless of whether the interfering uplink is to a non-geostationary satellite in a 250 km orbit, an 833 km orbit or a 20,200 km orbit.

Table A6.1-1. Results of Analysis of Interference from Non-Geostationary Satellite Uplinks into Non-Geostationary Satellite Uplinks (250 km Orbit)

Victim Satellite Parameters			
Orbital Altitude (km)	250	833	20200
Minimum Margin (dB)	28.2	22.0	12.6
Noise Power (dBW/Hz)	-199.58	-199.58	-199.58
Carrier Signal Power Density (dBW/Hz)	-172.51	-178.71	-188.11
Interfering Satellite Parameters			
Maximum Tx Power (dBW)	38.45	38.45	38.45
Earth Station Antenna Gain (dBi)	49.3	49.3	49.3
Maximum EIRP (dBW)	87.75	87.75	87.75
ES Antenna Off-Axis Angle (°)	24	15	3
ES Antenna Off-Axis Gain (dBi)	5.0	10.0	24.0
Frequency (MHz)	2050.0	2050.0	2050.0
Minimum Distance	250	833	20200
Space Loss (dB)	146.64	157.10	184.79
Victim Satellite Antenna Gain (dBi)	-5	-5	-5
Interfering Signal Power (dBW)	-108.19	-113.65	-127.34
Bandwidth of Emission (kHz)	4004	4004	4004
Interfering Signal Power Density (dBW/Hz)	-174.22	-179.67	-193.37
I + N (dBW/Hz)	-174.21	-179.63	-192.43
Net Link Margin (dB)	1.7	0.92	4.33

Simulations were run for each of the non-geostationary uplink into non-geostationary uplink interference cases to determine the statistics that the non-geostationary satellite would be located within the given off-axis angle of the boresight of the earth station antenna communicating with the geostationary satellite. The simulations were run for 1000 days at a time increment of 1 second. The earth station for the uplink to the non-geostationary satellite was located at 40N, 100W and the geostationary satellite was located at 100W. At each time increment in the simulation, the new position of the non-geostationary satellite is calculated and the pointing angle (azimuth and elevation) from the earth station location to the non-geostationary satellite is determined. The off-axis angle between this pointing angle and the pointing angle to the geostationary satellite is then calculated. The total time that the off-axis angle is less than the given angle is calculated. The number of events where the off-axis angle was within this angle is also calculated. An event begins the first time the off-axis angle is less than the given angle and ends when the off-axis angle is greater than the given angle. The longest duration of an event is also determined. Table A6.1-2 gives the results of these simulations for each of the non-geostationary satellite orbits.

Table A6.1-2 Results of Simulations

Orbital Altitude of victim satellite	Orbital Altitude of interfering satellite	Criterion Off-Axis Angle	Number of Events	Percentage of Total Simulation Time	Duration of longest event (minutes)	Duration of longest event (seconds)
250 km	833 km	24.0	175	0.0160%	3.93	236.0
250 km	20,200 km	24.0	582	0.0523%	3.83	203.0
833 km	250 km	15.0	115	0.0079%	3.1	186.0
833 km	20,200 km	15.0	433	0.0677%	4.78	287.0
20,200 km	250 km	3.0	106	0.0020%	0.816	49.0
20,200 km	833 km	3.0	95	0.0034%	1.283	77.0

The results of the analyses presented in this annex have shown that the off-axis angle of the interfering earth station may have to be large in order to ensure that the interference caused to a non-geostationary satellite uplink does not degrade the link margin significantly. However, simulations have shown that the probability of the two non-geostationary satellites being located such that the off-axis angle of the interfering earth station is within the given angle is small. The durations of these events are short in nature and do not occur too frequently.

Annex 7

Analysis of Interference between Government Geostationary Satellite Uplinks and GOES Satellite Uplinks in the 2025- 2110 MHz Band

A7.1 Introduction

In this annex, the potential interference between GOES satellite operations in the 2025 - 2035 MHz band and relocated Government geostationary satellite uplinks are investigated. The parameters for the relocated Government geostationary satellite uplinks are taken from the DoD interim report. The parameters for the GOES satellite uplinks are taken from the SRS. The analyses investigate the case where the orbital separation between the two geostationary satellites is 4°.

A7.2 Interference into DoD Geostationary Satellite Uplinks

The analysis of interference into the DoD satellite uplinks is performed using the minimum link parameters given in the DoD interim report. An elevation angle from the earth station to the satellite of 3° and an earth station transmitter power is 2000 watts are assumed. The satellite receive antenna is assumed to be omnidirectional with a gain of -5 dBi in all directions. The carrier power for this uplink is calculated by adding the minimum margin given in the DoD interim report (8.4 dB) and the system noise (-199.58 dBW/Hz, based on a receiver system noise temperature of 798.1K). As the margin is for an uplink operating at 1800 MHz and this analysis is investigating uplinks in the 2025 - 2110 MHz band, the margin is adjusted by the corresponding difference in space loss between the two frequencies. A center frequency of 2030 MHz is chosen in this analysis. This results in an additional 1.04 dB of space loss and the resultant minimum link margin is 7.36 dB.

For the interfering GOES uplinks, the maximum transmitter power levels that are in the ITU publications are used to determine the interference into the DoD satellite uplinks. For this analysis, it is assumed that the interfering earth station is located directly below the victim geostationary satellite (i.e., at the closest distance). The earth station antenna off-axis gain is calculated using Recommendation ITU-R S.465. The analysis calculates the interfering signal power at the victim geostationary satellite and then calculates the net link margin in the presence of this interference. The results of this analysis are shown in Table A7.2-1. The evaluation presented here is a worst-case analysis and the interference potential during operation is expected to be less than what is shown here.

Table A7.2-1. Results of Analysis of Interference into DoD Geostationary Satellite Uplinks from GOES Satellite Uplinks

Interfering Satellite	GOES West	GOES West-1	GOES East	GOES East-1
Orbital Longitude	135W	135W	75W	75W
Earth Station Antenna Gain (dBi)	47.0	49.6	47.0	49.6
Max Tx Power (dBW)	27.0	27.0	27.0	27.0
Max EIRP (dBW)	74.0	76.6	74.0	76.6
ES Antenna Off-Axis Angle (°)	4.5	4.5	4.5	4.5
ES Antenna Off-Axis Gain (dB)	15.68	15.68	15.68	15.68
Minimum Distance (km)	35786.0	35786.0	35786.0	35786.0
Frequency (MHz)	2030.0	2030.0	2030.0	2030.0
Space Loss (dB)	189.67	189.67	189.67	189.67
Victim Satellite				
Margin (dB)	7.36	7.36	7.36	7.36
Noise Power (dBW/Hz)	-199.58	-199.58	-199.58	-199.58
Carrier Signal Power Density (dBW/Hz)	-192.22	-192.22	-192.22	-192.22
Victim Satellite Antenna Gain (dBi)	-5.0	-5.0	-5.0	-5.0
Interfering Signal Power (dBW)	-151.99	-151.99	-151.99	-151.99
Bandwidth of Emission (kHz)	30	50	30	50
Interfering Signal Power Density (dBW/Hz)	-196.76	-198.98	-196.76	-198.98
I + N (dBW/Hz)	-194.94	-196.26	-194.94	-196.26
Net Link Margin (dB)	2.71	4.04	2.71	4.04

These results show that the net link margin of the Government geostationary satellite uplinks in the presence of interference from a GOES satellite uplink in the band 2025 - 2110 MHz will be greater than 2.7 dB when the satellites are separated by 4°. In those cases where the relocated satellite is located within 4° of a GOES satellite, further analysis would be necessary to determine if this orbital separation is sufficient to protect the geostationary satellite uplinks. In the case that orbital separation is not sufficient to protect the uplinks, frequency separation would be necessary to ensure compatible operation. It should be noted that there are very few GOES satellites and they only operate in the lower 10 MHz of the band.

A7.3 Interference from DoD Geostationary Satellite Uplinks into GOES Satellite Uplinks

For the analysis of interference from the DoD geostationary satellite uplinks into the GOES satellite uplinks, the maximum transmitter power for the DoD satellite uplinks is used. The received interfering signal power at the victim satellite is calculated using this power and the earth station off-axis antenna gain. The earth station antenna off-axis gain is determined using the figures given in the DoD interim report. This analysis assumes that the elevation angle from the interfering earth station to the victim satellite is 90°. For the GOES systems, the minimum EIRP levels in the SRS are used to determine the carrier signal power assuming a 3° elevation angle from the earth station to the satellite and an omnidirectional satellite receive antenna. The analysis calculates the net link margin in the presence of this interference. The results of this analysis are shown in Table A7.3-1. The evaluation presented here is a worst-case analysis and the interference potential during operation is expected to be less than what is shown here.

Table A7.3-1. Results of Analysis of Interference from DoD Geostationary Satellite Uplinks into GOES Satellite Uplinks

Victim Satellite	GOES West	GOES West-1	GOES East	GOES East-1
Orbital Longitude	135W	135W	75W	75W
Earth Station Antenna Gain (dBi)	47.0	49.6	47.2	49.6
Min Tx Power (dBW)	10.0	16.0	10.0	16.0
Min EIRP (dBW)	57.0	65.6	57.2	65.6
Distance @ 3° elevation (km)	41346.4	41346.4	41346.4	41346.4
Frequency (MHz)	2030.0	2030.0	2030.0	2030.0
Space Loss (dB)	190.93	190.93	190.93	190.93
Satellite Antenna Gain (dBi)	16.3	1.5	16.0	1.5
Carrier Signal Power Received (dBW)	-117.63	-123.83	-117.73	-123.83
Rcvr Noise Temperature (K)	1320.0	864.0	1320.0	864.0
Bandwidth (kHz)	200	1000	200	1000
System Noise Power (dBW)	-144.38	-139.23	-144.38	-139.23
Interfering Satellite				
Earth Station Tx Power (dBW)	38.45	38.45	38.45	38.45
Earth Station Max Gain (dBi)	49.3	49.3	49.3	49.3
Earth Station EIRP (dBW)	87.75	87.75	87.75	87.75
Bandwidth of Emission (kHz)	4004	4004	4004	4004
Tx Power in Victim Bandwidth (dBW)	25.44	32.43	25.44	32.43
ES Antenna Off-Axis Angle (°)	4.5	4.5	4.5	4.5
ES Antenna Off-Axis Gain (dBi)	18.0	18.0	18.0	18.0
Minimum Distance (km)	35786.0	35786.0	35786.0	35786.0
Space Loss (dB)	189.67	189.67	189.67	189.67
Victim Satellite Antenna Gain (dBi)	16.3	1.5	16.0	1.5
Interfering Signal Power Received (dBW)	-129.94	-137.75	-130.24	-137.75
I + N (dBW)	-129.78	-135.42	-130.07	-135.42
Net Link Margin (dB)	12.16	11.59	12.35	11.59

These results show that the net link margin for a GOES satellite uplink in the presence of interference from a relocated Government geostationary satellite uplink in the band 2025 - 2110 MHz will be greater than 11.5 dB when the satellites are separated by 4°. In those cases where the relocated satellite is located within 4° of a GOES, further analysis would be necessary to determine if this orbital separation is sufficient to protect the geostationary satellite uplinks. In the case that orbital separation is not sufficient to protect the uplinks, frequency separation would be necessary to ensure compatible operation. It should be noted that there are very few GOES satellites and they only operate in the lower 10 MHz of the band.

APPENDIX E: Comparison of Transmit EIRP from a Metropolitan Area

In the evaluation of the interference to satellite TT&C links one of the intermediate values computed is the EIRP radiating from a collection of IMT-2000 base stations located with-in a metropolitan area. This contribution illustrates the difference between the methodology utilized in the DOD interim report and that proposed in the industry working group on satellite control stations [i, ii].

As a starting point considers the city of New York, the population utilized in the DOD interim report states that 7.2 million people reside in that area [iii]. Shown in Table 1 is the EIRP radiated from this metropolitan area by applying the methodology found in [iii].

Table 1: DOD Interim report computation of EIRP from New York.

Population	7.3 Million	Note
Transmit EIRP	0.04 W/Hz	= 38μW/km^2/Hz * Pop * 144.2 km^2/Million
	-14.0 dBW/Hz	Constant value as a function of elevation

Shown in Table 2 is the upper bound on the Peak EIRP for the same population base utilizing the approach found in [ii].

Table 2: Industry working group computation of EIRP from New York.

Population	7.3 Million	Note
R_p	36.64 km	
η_p	91%	Penetration of IMT-2000 Systems
N_{bs}	15	Upper bound on Number of base stations
$P_{\max}$	-43 dBW/Hz	Power supplied to the antenna, Computed from parameters found in [iv] for UWC-136 base station with 200 kHz operating bandwidth. CDMA-2000, W-CDMA and TD-CDMA all have lower transmit power densities.
G_0	17 dBi	Peak Gain of Base Station
EIRP (Peak)= $N_{bs} * P_{\max} * G_0$	-14.24 dBW/Hz	Peak EIRP
ϕ_{dt}	2.5°	Down Tilt of Antenna

The EIRP as a function of the elevation angle from the city for the two approaches in shown in Figure 1. As shown in Figure 1 the two approaches arrive at significantly different radiated powers from this metropolitan area.

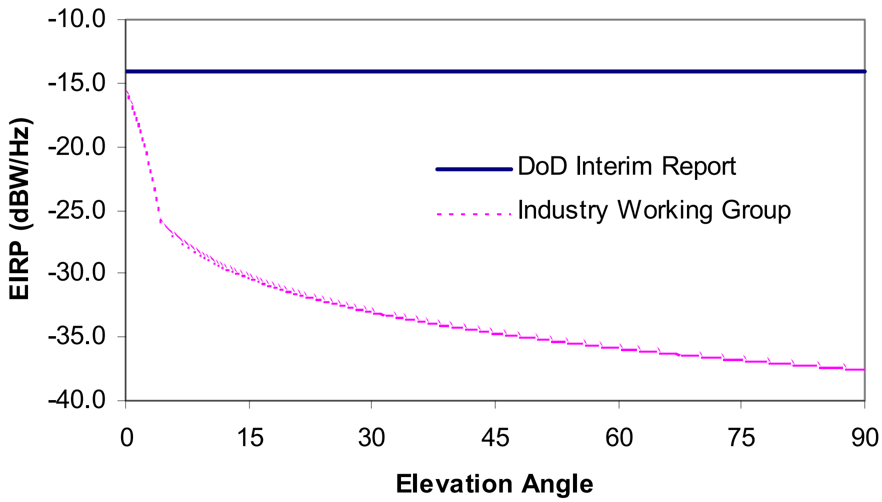

Figure 1: Differences in EIRP from a metropolitan area.

Shown in Figure 2 is the interference power received by a satellite at an altitude of 250 km. This figure indicates that, in general for elevation angles above 4.2 degrees, the approach utilized in the DoD interim report results in 11.7-17.3 dB higher levels of interference.

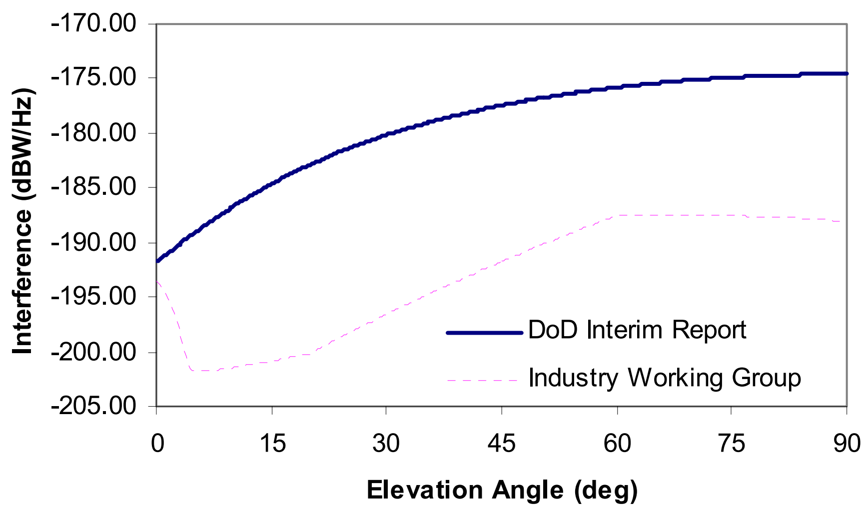

Figure 2: Interference power at 250 km from a metropolitan area.

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[i] "Investigation of the technical feasibility of accommodating the international mobile telecommunications (IMT) 2000 within the 1755-1850 MHz band," Department of Defense IMT-2000 Technical Working Group, Interim Report, 27 October 2000.

[ii] "Interference Methodology to Assess Interference from Base Stations to Satellite Control Systems," R. Kubik, 2/19/01, Rev.5.

[iii] "Methodology for determining the on-orbit signal levels due to an aggregate IMT 2000 environment," Distributed at 12/1/00 Government-Industry outreach meeting.

[iv] “Characteristics of IMT-2000,” Industry working group on IMT-2000 characteristics, 1/5/01.

Industry Working Group
on Fixed and Tactical Radio Relay

Report

Evaluation of Sharing between International Mobile Telecommunications (IMT) 2000 Technology and Fixed and Tactical Radio Relay in Band 1755-1850 MHz

Chair: Larrie Sutliff

20 February 2001

Executive Summary

The goal of this industry group is to review and evaluate sharing between IMT-2000 operations and fixed and tactical radio relay systems operating in the band 1755-1850 MHz. The working method of this group was to first evaluate and analyze the interference/sharing scenarios between SCS and IMT-2000. In cases where sharing on a co-frequency, co-location basis is not feasible the goal of this group is to evaluate mitigation techniques and/or discuss alternative bands for use of or relocation of fixed and tactical radio relay operations.

This report is summarized in more detail below but initial conclusions are the following:

- **Sharing with Fixed Point-to-Point**
    - Analyses indicate that sharing is not possible.
        - Mobile ubiquity precludes sharing at same place, time and frequency.
    - Relocation of fixed point-to-point systems is feasible.
        - The process will be similar to that used for PCS services.
- **Sharing with Tactical Radio Relay**
    - Geographic sharing is feasible.
        - Heaviest DoD demand is in rural areas.
        - Heaviest IMT-2000 demand is in urban areas.
    - Band segmentation on a geographic basis is envisioned as the sharing solution.
        - A requirement for usage is to be tailored to the operational area of tactical radio relay equipment.
    - Additional capacity could be provided via access to other bands in which the equipment can operate.
        - Frequency agility of tactical radio relay is key to sharing.

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1 Conventional Fixed Point-to-Point Systems

The NTIA interim report states that numerous federal agencies, including DoD, United States Department of Agriculture, Department of the Interior, U.S. Coast Guard, Department of Justice, and the Department of Energy, have conventional fixed operations in the 1710-1850 MHz band.[1]

1710-1755 MHz - As a result of the Balanced Budget Act of 1993 the 1710-1755 MHz portion of the band was reallocated for non-government use and most of the conventional fixed point-to-point links operating in this portion of the band have been, or will be, relocated.[2] Certain systems, however, are exempt from reallocation.[3] This includes fixed microwave stations used by Federal Power Agencies (FPAs), and certain fixed stations involving safety-of-life operations.

1755-1850 MHz – The NTIA interim report states that there are 3836 assignments for fixed services in the 1755-1850 MHz band.[4] Interference will occur between IMT-2000 and conventional fixed operations in a relatively limited area around each fixed facility.

Because of the wide-spread deployment of both systems, it is not feasible for IMT-2000 to share with fixed point-to-point microwave systems on a time, geographic, or frequency basis. These fixed systems are however, very similar to those used by the private sector, which were relocated to allow introduction of PCS in the 1.9 GHz band, see Appendix C and D for more detail. It is feasible to relocate these systems to commercial systems, fiber optic, frequency bands above 3 GHz that are available for Government fixed point-to-point systems, or, possibly, non-government frequency bands available for point-to-point operations in cases where a link can not be accommodated by other means.

Accordingly, either band segmentation or full relocation of the conventional fixed services is necessary if IMT-2000 is to be accommodated. Many of the Federal Government fixed point-to-point systems are analog and have been in use for many years. Relocation provides an opportunity to upgrade the quality and reliability of these systems to more efficient digital operations. As noted in the NTIA report, aging analog equipment operating in the 1710-1850 MHz band will eventually require replacement. However, due to the reallocation of services from the band, there is no digital equipment available to replace the existing systems in this band.[5] Some Federal users, such as the U.S. Coast Guard and the Department of Justice, have already begun to transition fixed operations into higher frequency bands.[6] Relocation as part of

[1] "Federal operations in the 1755-1850 MHz band: The potential for accommodating third generation mobile systems," NTIA Interim Report, November 15, 2000 at p.22.

[2] *Id* at p.23.

[3] "Investigation of the technical feasibility of accommodatin the international mobile telecommunications (IMT) 2000 within the 1755-1850 MHz band," Department of Defense IMT-2000 Technical Working Group, Interim Report at Appendix E.

[4] See NTIA Interim Report *supra* note 1 at table 6, p. 15.

[5] *Id* at p. 24.

[6] *Id* at p. 23.

an effort to provide spectrum for IMT-2000 provides an opportunity for Federal users to be fully compensated for the cost of relocation and to upgrade systems to more reliable and spectrally efficient digital operations. The advantages of and mechanisms for relocation are described below.

1.1 Advantages of relocation

Many of the Federal Government are analog systems that have been in use for many years. Relocation provides an opportunity to upgrade the quality and reliability of these systems to more efficient digital operations. As noted in the NTIA report, aging analog equipment operating in the 1710-1850 MHz band will eventually require replacement. However, due to the reallocation of services from the band, there is no digital equipment available to replace the existing systems in this band.[7] Some Federal users, such as the U.S. Coast Guard and the Department of Justice, have already begun to transition fixed operations into higher frequency bands.[8] Relocation as part of an effort to provide spectrum for IMT-2000 provides an opportunity for Federal users to be fully compensated for the cost of relocation.

1.2 Relocation of Fixed services

There are several viable options for relocation of fixed services that should be considered in the following order. As more fully described in a contribution to the Association Group (see Appendix A), it appears to be feasible to relocate all of the conventional fixed operations to other frequency bands or satisfy the communications requirements through other means. Relocation methods of relocation should be considered as follows:

1.2.1 Relocation to Alternative Media or Other Commercial Services

The use of alternative media may be an attractive means of satisfying the requirements of the affected agency without the use of fixed microwave. The use of commercially available services may also be cost effective. As a result, the preferred option for relocation of Federal fixed microwave systems in the 1710-1850 MHz band should be to move such systems to alternative media or other commercial services.

1.2.2 Relocation to Federal Government Bands

If it is not practicable to use alternative media or other commercial services, the affected systems should be relocated to available spectrum that is allocated to the Federal Government on an exclusive-use basis. This will provide the agencies with the maximum flexibility in accommodating the affected systems without the need to coordinate with the private sector. The following bands have been identified for consideration:

4400-4990 MHz

7250-8400 MHz

These bands are currently available for Government fixed operations and should be the first frequency bands considered for relocation, see Appendix D.

1.2.3 Relocation to Non-Federal Government Bands

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[7] *Id* at p. 24.

[8] *Id* at p. 23.

If alternative spectrum cannot be found in bands allocated to the Federal Government, consideration should be given to relocating these affected Federal systems to bands that are allocated for non-Federal use. In this case, it will be necessary to review regulatory issues associated with Federal agencies using non-Federal bands. The following bands have been identified for consideration:

3700-4200 MHz

5925-6425 MHz

6525-6875 MHz

6875-7075 MHz

7075-7125 MHz

10.55-10.68 GHz

10.7-11.7 GHz

2 Tactical Radio Relay

Tactical Radio Relay systems are similar to conventional fixed systems except that they operate on a transportable basis. Similar to conventional fixed systems, interference between IMT-2000 and tactical radio relay will occur in a localized area around the tactical radio relay system. All of the tactical radios described in the NTIA and DoD interim reports are capable of operating over a large amount of spectrum, ranging from 1350-1850 MHz for current systems to 1350-2690 MHz for new systems and are capable of tuning to channels centered every 125 kHz in this range. However, in its interim report, DoD states that MSE systems rarely have access to spectrum outside of 1350-1390 MHz and 1710-1850 MHz and that the DWTS systems typically use the 1350-1390 MHz, 1432-1435 MHz, and 1710-1850 MHz bands.[9]

During discussions as part of the Association group meetings, requirements for tactical radio relay operations were described as being very heavy during the largest scale military training operations with declining requirements for smaller scale operations. The NTIA interim report provides information on the location of training areas in which tactical radio relay systems operate, but not provide detailed information on the operational aspects, such as the frequency or size of training operations at each location. It is reasonable to assume, however, that the largest scale training exercises would be conducted in the most remote areas where a large deployment of troops have the room required to maneuver, whereas training closer to more suburban areas would be of limited scope. Based on this, it is reasonable that the military requirements for tactical radio relay are greatest in very remote areas and are increasingly modest in areas closer to major population centers where you would expect smaller troop deployments.

Considering the above assumptions, is should be feasible to develop a sharing plan between 3G systems and tactical radio relay systems that provides access to most of all of the spectrum in the 1710-1850 MHz band for 3G in urban areas, where demand or commercial services is greatest,

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[9] See DoD Interim Report *supra* note 3 at p. 2-3

and provides spectrum for military training with increasing amounts available in progressively rural areas as 3G demand decreases and the military requirements increase. Frequency coordination will have to be well defined to ensure that each IMT-2000 operator will have access to a minimum amount of spectrum nationwide in order to ensure that customer requirements can be met. One approach that was examined involved the concept of "listen before transmit" being incorporated in the 3G systems, the group concluded that in general this approach is not feasible, see Appendix B for more detail.

Under this approach, if each 3G licensee has access to 2x15 MHz of spectrum it would be feasible for DoD to use 2x5 MHz in training located outside of major urban centers where 3G spectrum requirements are decreasing. For military bases located in even more remote areas, it would be possible for DoD to use 2x10 MHz of a licensees' spectrum. Accordingly, even if the entire 1710-1850 MHz band were made available immediately for use by IMT-2000, it would be possible for DoD to have access to the majority of the band for its tactical radio relay requirements in training areas where its needs are greatest, while still providing sufficient capacity for IMT-2000 to meet demand for service. It will be necessary to have a more detailed investigation of the requirements at the various training areas as to the exact requirements

In addition to the above geographic approach to sharing spectrum in the 1710-1850 MHz band, to the extent that spectrum at 1710-1850 MHz is paired with spectrum in another band, it is also reasonable for DoD to also use the portion of the pair outside of 1710-1850 MHz. This will provide DoD to access to additional spectrum in rural areas.

The above sharing mechanism requires prior agreement as to which channels would be used by DoD it order to ensure that all of an IMT-2000 licensee's spectrum is not being used by DoD in an area, further detail is given in Appendix E. An example of how such an approach could work is given below.

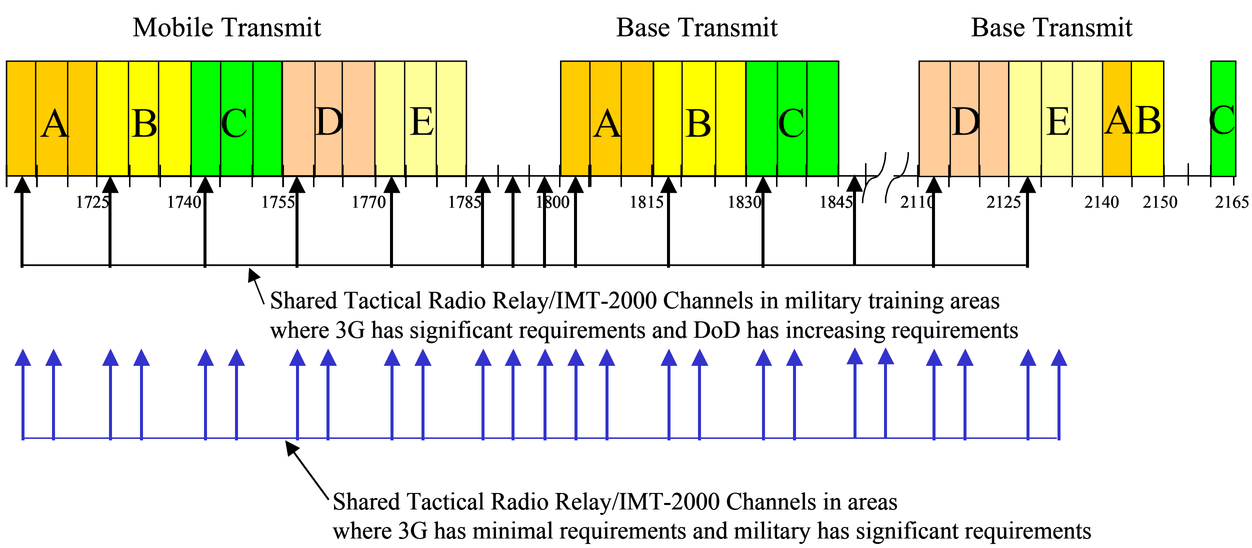

Figure 1: Example of shared use between Tactical Radio Relay and IMT-2000 operations.

The above approach provides DoD with access to almost as much spectrum as they currently have in rural areas while providing IMT-2000 access to sufficient spectrum to meet its requirements in a variety of operating environments, ranging from dense urban to rural. In developing sharing rules for this approach guidelines should be established so that DoD users first select channels in bands not used for IMT-2000, or in IMT-2000 guardbands. As additional channels are required, DoD users would then use shared channels.

In addition, to the extent that tactical radio relay systems have the capability to tune to channels in frequency bands currently available only to non-Government users, the FCC should consider sharing rules that would allow Government users access these bands in areas geographic areas where non-Government requirements are minimal. Such access could be through strict regulatory sharing arrangements or through more flexible approaches such as those being considered in the Commission's proceeding looking secondary markets.[10]

NTIA and DoD interim reports indicate that current systems are being replaced by systems that operate over an even wider expanse of spectrum. Accordingly, this is an opportunity to facilitate deployment the new systems, and to the extent that additional frequency bands are identified that could accommodate this use, compensation could be provided to further expand the frequencies and capabilities of the system. More efficient use of the U.S. spectrum resource could also be possible through greater shared use of non-Government bands for Government operations. In this case, mechanisms should be considered that would allow these Government systems to use non-Government bands that they do not currently have access to in geographic areas where non-Government use of a frequency band is limited. Because DoD conducts training operations around the world, including areas where the 1710-1850 MHz band is used for commercial mobile operations, a movement away from this band as a primary band for these systems will allow DoD to operate in a manner more compatible with the global use of spectrum. This is also advantageous in limited combat or peacekeeping missions where operations may interference with or cause interference to friendly countries not involved in the conflict or supporting U.S. efforts.

[10] *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, Notice of Proposed Rule Making, WT Docket 00-230, released November 27, 2000, FCC 00-42.

APPENDIX A: Relocation of federal fixed systems from the 1710-1850 MHz band

Industry-Government 3G Spectrum Committee
Fixed and Tactical Radio Relay Working Group

Contribution

Title: Relocation of federal fixed systems from the 1710-1850 MHz band.

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Summary:

This contribution identifies options for the relocation of Federal fixed microwave systems operating in the 1710-1850 MHz band. Relocation is both desirable and necessary to accommodate 3G mobile systems in the band. It is recommended that relocation be accomplished using methods similar to those employed in the FCC's proceeding to accommodate "emerging technologies" in the 2GHz band – i.e., through the use of commercially available services, alternative media (such as fiber optic cable and satellites), and/or relocation to frequency bands above 3 GHz. It is recommended that both Federal and non-Federal bands be considered as alternate spectrum, and several candidate bands are identified.

Background and Discussion:

1. Introduction

This contribution identifies options for the relocation of fixed microwave systems currently operating in Federal Government bands that were identified by the 2000 World Radiocommunication Conference (WRC-2000) for Third Generation (3G) mobile systems, also called International Mobile Telecommunications – 2000 (IMT-2000). In its interim report, NTIA tentatively concluded that co-channel sharing with IMT-2000 does not seem to be feasible due to the number and distribution of Federal fixed stations in the United States.[1] If IMT-2000, or other advanced mobile services, were to be implemented in this band, these fixed systems would have to be relocated.

[1] *See* "Federal Operations in the 1755-1850 MHz Band: The Potential for Accommodating Third Generation Mobile Systems", *Interim Report*, National Telecommunications and Information Administration, November 15, 2000.

2. Affected Federal Systems

2.1 1710-1755 MHz Band

The 1710-1755 MHz band is used extensively for Federal fixed point-to-point microwave communications, military tactical radio relay, and airborne telemetry systems.[2] It was reallocated to the private sector in 1993, and most of the systems operating in the band will be cleared from the band by January 2004. Certain systems, however, are exempt from reallocation.[3] This includes fixed microwave stations used by Federal Power Agencies (FPAs), and certain fixed stations involving safety-of-life operations. While these fixed systems are exempt from reallocation, they are eligible for compensation for relocation to another frequency band. It is recommended that these fixed systems also be relocated to accommodate the development of advanced mobile services.

2.2 1755-1850 MHz Band

The 1755-1850 MHz band supports a variety of Federal functions, including medium-capacity, conventional fixed microwave communication networks.[4] These networks support backbone communications systems for many Federal agencies, including the Department of Defense, the Forest Service of the U.S. Department of Agriculture, the Department of Justice, the Department of the Interior, and the Department of Energy. Applications include law enforcement, emergency preparedness, support for the national air space system, military command and control networks, and control links for various power, land, water, and electric-power management systems.

3. Relocation Requirements

The National Defense Authorization Act for Fiscal Year 1999 (NDAA-99) provides for reimbursement of relocation costs for Federal agencies affected by reallocation of spectrum to the private sector.[5] The reimbursement process is currently being developed by NTIA.[6] NDAA-99 also requires that affected Federal agencies be provided suitable replacement spectrum, if necessary. As a result, the availability of alternative spectrum is important to the long term prospects for accommodating 3G in the 1710-1850 MHz band.

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[2] *See* "Spectrum Reallocation Final Report, Response to Title VI – Omnibus Budget Reconciliation Act of 1993", *Final Report*, NTIA Special Publication 95-32, February 1995.

[3] *Final Report,* Appendix E.

[4] *NTIA Interim Report,* p. 13.

[5] See National Defense Authorization Act for Fiscal Year 1999, Pub. L. 105-261, 112 Stat. 1920.

[6] *See* "Mandatory Reimbursement Rules for Frequency Band or Geographic Relocation of Federal Spectrum-Dependent Systems", *Notice of Proposed Rulema*king, National Telecommunications and Information Administration, U.S. Department of Commerce, January 2001.

4. Relocation Options

In determining the viability of making spectrum in the range 1850-2200 MHz (“2 GHz”) available for “emerging technologies”, the Commission conducted a study and found that spectrum at higher frequencies, particularly in the 3-7 GHz range is suitable for relocation of systems operating at 2 GHz.[7] It also determined that the use of alternative media, such as fiber optic cable and satellites, may offer a more attractive means of maintaining some of the services. Considering the similarity between the Federal fixed microwave systems operating in the 1710-1850 MHz band and the non-Federal systems considered in the FCC’s proceeding, it is reasonable to apply a similar approach here. Consequently, it is recommended that affected Federal agencies consider the following relocation options: (1) relocation to alternative media or other commercial services, (2) relocation to Federal Government bands, and (3) relocation to Non-Federal Government Bands.

4.1 Relocation to Alternative Media or Other Commercial Services

Given the demand for spectrum, particularly below 3 GHz, fixed communications systems should be accommodated using non-spectrum-based technologies to the extent practicable. As noted previously, the use of alternative media may be an attractive means of satisfying the requirements of the affected agency without the use of fixed microwave. The use of commercially available services may also be cost effective. As a result, the preferred option for relocation of Federal fixed microwave systems in the 1710-1850 MHz band should be to move such systems to alternative media or other commercial services.

The NTIA Interim Report implies that fixed microwave links are only operated in the 1755-1850 MHz band if commercial service is unavailable, excessively expensive, or unable to meet required reliability.[8] However, the cost and availability of alternative media and commercially available services may have changed considerably since those systems were deployed.

4.2 Relocation to Federal Government Bands

If it is not practicable to use alternative media or other commercial services, the affected systems should be relocated to available spectrum that is allocated to the Federal Government on an exclusive-use basis. This will provide the agencies with the maximum flexibility in accommodating the affected systems without the need to coordinate with the private sector. The following bands have been identified for consideration:

- 4400-4990 MHz
- 7250-8400 MHz

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[7] *See* “Creating New Technology Bands for Emerging Telecommunications Technologies”, OET/TS 91-1.

[8] *Interim Report*, p. 14.

4.3 Relocation to Non-Federal Government Bands

If alternative spectrum cannot be found in bands allocated to the Federal Government, consideration should be given to relocating these affected Federal systems to bands that are allocated for non-Federal use. In this case, it will be necessary to review regulatory issues associated with Federal agencies using non-Federal bands. The following bands have been identified for consideration:

- 3700-4200 MHz
- 5925-6425 MHz
- 6525-6875 MHz
- 6875-7075 MHz
- 7075-7125 MHz
- 10.55-10.68 GHz
- 10.7-11.7 GHz

APPENDIX B: A proposed answer to NTIA Question I.B, "The NTIA Interim Report suggested a coordination method for 3G systems to operate near federal radio sites. Is the concept of a listen-before-transmit base station feasible?"

Industry-Government 3G Spectrum Committee
Fixed and Tactical Radio Relay Working Group

Contribution

Title: A proposed answer to NTIA Question I.B, "The NTIA Interim Report suggested a coordination method for 3G systems to operate near federal radio sites. Is the concept of a listen-before-transmit base station feasible?"

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Date: January 31, 2001

Document Summary:

No.

Recommendations and Notes of Importance:

Assuming spectrum sharing between DoD tactical radio systems and 3G base stations, the onus of "listen-before-transmit" is more appropriately placed upon the tactical systems than the 3G base stations.

1. INTRODUCTION

Among its questions submitted to industry, the NTIA asked the following:

> Question I.B – The NTIA Interim Report suggested a coordination method for 3G systems to operate near the Federal radio sites. Is the concept of a listen-before-transmit base station feasible?

2. DISCUSSION

Listen-before-transmit is not suitable for 3G base stations because 3G technologies such as WCDMA and EDGE use base stations that transmit at least one carrier frequency continuously. The frequencies are changed only when system re-tunes are performed, which in most systems is no more frequent than once per week, and typically much longer (weeks or months). With such constant-carrier systems, there is no opportunity to listen before transmitting, since the base stations are transmitting all the time. During system re-tunes, frequency selection for rural sites is often not flexible, since it is driven by the frequency plan requirements of neighboring suburban and urban areas (i.e., the rural frequencies must be chosen so as not to interfere with frequencies in neighboring cells).

When EDGE base stations expand in capacity beyond a single carrier, the possibility of frequency hopping exists. The second carrier (not the carrier with the control channel on it) can hop between pre-determined sets of frequencies on time scales of roughly 0.5 second. No capability presently exists for a "listen-before-transmit" mode on the frequency hopping carriers, however.

While the details of government tactical radio systems operating at the federal radio sites are not known by carriers, our understanding is that they are set up on a temporary (days or weeks) basis, and then shut down until the next training session (i.e. the long-term duty cycle is less than, say, 50%, compared to 100% for 3G base stations).

Technically, the onus of listen-before-transmit is best relegated to the system that operates with lowest duty cycle, which in this case is the tactical system.

3. CONCLUSION

The concept of listen-before-transmit 3G base stations is not feasible, since they operate with essentially 100% duty cycles, and frequency re-tunes are tightly coupled to frequency requirements throughout the RF network.

If base stations and tactical DoD radios must share the same spectrum, the responsibility for listen-before-transmit is best left to the tactical radios, since they operate with duty cycles less than 100%.

APPENDIX C: FUNDAMENTALS OF MICROWAVE FREQUENCY COORDINATION

Industry-Government 3G Spectrum Committee
Fixed and Tactical Radio Relay Working Group

Contribution

Title: **FUNDAMENTALS OF MICROWAVE FREQUENCY COORDINATION**

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Document Summary:

This is a primer on the FCC Part 101 frequency coordination process used by non-government microwave operators to coordinate their frequency usage with each other. This process has been used successfully by PCS operations in the 1850 – 1900 MHz band to coordinate their usage with incumbent microwave operators.

Recommendations and Notes of Importance:

Comsearch recommends that this process be considered with respect to its applicability to coordinating frequency usage between government operators in the 1710 – 1855 MHZ band, and new entrants in this spectrum under consideration for 3G systems.

FUNDAMENTALS OF MICROWAVE FREQUENCY COORDINATION

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Frequency Coordination

Frequency Coordination is a bilateral process that involves the cooperative sharing of technical operating information between parties utilizing the same spectrum. The procedures are based upon the Federal Communications Commission's (FCC) coordination and licensing requirements found in Rule Part 101, as well as related industry practices that have evolved over the years.

Background

In the late 60's and early 70's, the FCC was faced with numerous competing radio applications for spectrum in the Common Carrier frequency bands. The FCC's primary method of sorting through these applications was to hold a comparative hearing to determine who was most qualified to use the spectrum. These hearings were typically long and tedious as competing parties debated the merits of their respective cases and resulted in significant delays in the granting of licenses.

In an effort to improve the licensing process, the FCC established the requirement for Common Carrier microwave operators to coordinate planned frequency usage with each other in advance of filing related applications. This requirement, known as frequency coordination, has been in effect since 1971 and has significantly streamlined the application and licensing process. It effectively minimizes the potential for mutually exclusive applications, interference conflicts, and the demands placed on FCC resources.

In 1996, the FCC adopted Rule Part 101 which combined the Private and Common Carrier point-to-point frequency bands under one consolidated Rule Part. As part of this consolidation, the FCC acknowledged the many benefits of the coordination process and decided to implement this requirement for both Private and Common Carrier microwave license applicants.

Frequency Coordination Process

The Frequency Coordination Process involves several distinct but interrelated elements; interference analysis, notification, and response.

Interference Analysis - The first step in the frequency coordination process is the interference analysis. The FCC requires that applicants engineering a new system or making modifications to an existing system must conduct the appropriate studies and analyses to avoid interference in excess of permissible levels to other users. This interference analysis is performed by the applicant prior to issuing a prior coordination notice (PCN) and is also performed by recipients of a PCN to verify non-interference.

Interference Analysis is an iterative process that involves computerized simulation of potential interference and an engineering analysis to eliminate interference cases. The process begins with a tentative frequency selection consistent with the established frequency plan in place. High-speed, automated calculations are conducted utilizing

Telecommunication Industry Association (TIA) Bulletin 10 criteria and industry developed guidelines. These calculations include co-channel and adjacent channel

interference, threshold degradation, adjacent spectrum interference; and potential interference from intermodulation products. In frequency bands shared with satellite earth stations, an interference analysis is conducted with the applicable ground and space segments.

Notification - Once an interference analysis has been completed, and prior to system implementation, an operator is required to notify all "potentially affected parties". The industry defines an operator as potentially affected if his facilities (including proposed, applied-for, or operating) fall within a defined coordination distance and operate in the same frequency band. This notice is referred to as a prior coordination notice (PCN) and contains the technical operating parameters and a general description of the proposed system.

The FCC Rules make allowance for two types of notification, both oral and written. The "written" PCN is the standard type and is conveyed by mail, fax or electronic media. The PCN includes a requested response date to coincide with the 30 day period allowed under FCC Rule. An oral PCN or "Verbal Coordination" is employed when an expedited response time of less than 30 days is required. These PCNs are typically forwarded electronically and are often followed up by telephone to ensure a quick response. The recipient of a verbal coordination is under no obligation to respond quicker than the 30 days allowed under the Rules, however the industry typically acknowledges these requests and makes every attempt to respond accordingly.

Response - As stated previously, the recipient of a PCN has 30 days in which to analyze the proposal and respond. Every attempt should be made by the receiving party to respond as soon as possible. In most cases, operators utilize an outside agent, commonly referred to as a "protection agent" to administer this function. The response to a PCN should include an affirmation of the proposal, or if there are objections, a detailed description of the reasons why. Typically, a response raising concerns will contain technical data sufficient to substantiate the objection.

The party issuing the PCN then is required to resolve all potential conflicts raised to the satisfaction of the objecting party. This may require several rounds of discussion, technical analysis, and negotiation. When both parties have reached an agreeable resolution of the cases, the coordinator of the proposed system issues a document called a Supplemental Showing. The Supplemental Showing is akin to a signed affidavit in which the coordinator attests to satisfactorily completing coordination. There are occasions when conflicts remain unresolved after repeated attempts to negotiate a solution. If the situation occurs, the Rules require that it should be noted on the Supplemental Showing. Once coordination is satisfactorily completed, the signed Supplemental Showing is attached to the license application.

APPENDIX D: Response to Art Lane's e-mail of 1/9/01 concerning relocation cost and frequencies

Industry-Government 3G Spectrum Committee
Fixed and Tactical Radio Relay Working Group

Contribution

For Consideration By: {Migration SWG}

Title: Response to Art Lane's e-mail of 1/9/01 concerning relocation cost and frequencies.

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Document Summary:

I don't know an average relocation cost for the 1850 to 1990 MHz band but I believe the industry accepted planning figure was $250k per hop. Actual prices could have been higher due to the incentives that the PCS providers offered in order to speed up the relocation. Many (most?) private users had lightly loaded 600 channel analog radios that were converted to 1 DS3 digital radios necessitating additional cost multiplex and terminating equipment. Also, to meet the original availability objectives, most of the longer 2 GHz paths could only be accommodated in the 6 GHz bands which, in many cases, required new towers to withstand the larger antenna structural loads and the tighter twist and sway requirements.

Government users currently in the 1755 – 1850 MHz band have two possible relocation bands of which I'm aware. One is the remainder (part has already been reallocated) of the 4.4 to 5.0 GHz band and the other is the 8 (7.1 – 8.5) GHz band. Either is suitable for typical telecommunications capacities and path lengths however 2 GHz has higher power amplifiers and grid antennas that reduce tower loading. Alcatel is the contractor for the FAA fixed microwave links and several years ago they switched from the 2 GHz to the 8 GHz band. I do not know of any great increase in system cost to them. I believe the choice of the 8 GHz band was due primarily to ready availability of equivalent replacement radios and adequate spectrum. There may also have been some frequency coordination issues with some of the 4 GHz band equipment (radars?).

Recommendations and Notes of Importance:

APPENDIX E: Consideration of Mitigation and Sharing Techniques For Tactical Radio Relay Systems and IMT-2000

Industry-Government 3G Spectrum Committee
Fixed and Tactical Radio Relay Working Group

Contribution

Title: Consideration of Mitigation and Sharing Techniques For Tactical Radio Relay Systems and IMT-2000

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Date: January 12, 2001

Document Summary:

This document discusses mitigation techniques suggested in the NTIA and DoD interim reports for sharing between tactical radio relay systems and IMT-2000 systems and provides additional proposals for sharing and for other bands that could be used to satisfy the operational requirements of tactical radio relay systems.

Recommendations and Notes of Importance:

The document recommendation is that a combination of sharing and use of additional frequency bands should provide a feasible method for satisfying the operational requirements of tactical relay systems while making sufficient spectrum available for IMT-2000 systems.

Consideration of Mitigation and Sharing Techniques
For Tactical Radio Relay Systems and IMT-2000

With respect to tactical radio relay, the NTIA and DoD reports describe four radio systems that operate in the band of interest providing central communications as part of an integrated communications network. These systems are:

MSE - AN/GRC-226(V)2
Frequency Range: 1350-1850 MHz
Min. Duplex Spacing: 50.125 kHz
Waveform: 2M40F9W

HCLOS – AN/GRC-245(V)
Frequency Range: 225-400 & 1350-2690 MHz
Min. Duplex Spacing: 50.125 kHz
Waveform: 2M50W1D

DWTS – AN/MRC-142 (Shore based)
Frequency Range: 1350-1850 MHz
Min. Duplex Spacing: 62 kHz
Waveform: 610k0F7W

DWTS – AN/SRC-57 (Ship-based)
Frequency Range: 1350-1850 MHz
Min. Duplex Spacing: 50 MHz for ship-to-ship
62 for ship-to-shore
Waveform: 2M85F7D

These systems operate in numerous areas throughout the U.S. during military training operations. (See figures 6 and 7 of the NTIA report).

Mitigation Methods Considered:

1) **Listen Before Talk** – NTIA has suggested that one solution that for co-channel operation in protected areas that encompass military training locations would be for IMT-2000 systems to employ a listen-before-talk feature whereby the IMT-2000 base station would determine whether a frequency is in use prior to transmitting and would not assign any channels currently occupied by DoD systems. One difficulty with such an approach would be that, without prior coordination for frequency use, there would be the potential for DoD operations to occupy all of the spectrum licensed to a particular operator. Thus the operator would have no usable capacity and would not be able to serve its subscribers for some period of time. This would clearly be an unacceptable situation for the operator. Accordingly, it would be preferable if prior arrangements could be

made to ensure available capacity for the licensed operator by limiting the operations of DoD systems to certain band segments.

2) **Cross Polarization** – The DoD report suggests that antenna cross-polarization between IMT-2000 base stations and tactical radio systems would reduce the level of interference between the systems. While it is true that cross-polarization can provide a significant increase in isolation between two systems, limiting the polarization of an IMT-2000 system will likely result in unacceptable system performance. It is not possible to provide a well defined path between a mobile subscriber unit and a IMT-2000 base station. To maintain the performance of the IMT-2000 system, it is necessary to match as closely as possible the polarization of the mobile and base signals. In a mobile service, however, especially one which is heavily dominated by portable rather than mobile units, the orientation of the mobile unit is difficult to predict and the signal received at the base station may be the product of various reflections effecting the polarization of the signal. Accordingly, for optimum performance, IMT-2000 base stations must include both vertical and horizontal polarization components.

3) **Frequency Separation** – Frequency separation appears to be the most promising mitigation method to avoid interference. Two approaches to frequency separation are discussed. The first method would be for the tactical radio systems to operate outside of the 1710-1850 MHz band. The second would be for tactical radio systems to limit operations to certain portions of the 1710-1850 MHz band in a way that would ensure that, while an IMT-2000 licensee wouldn't have access to all of its licensed spectrum in an area, it would be assured of having spectrum on which in could operate and meet the needs of its subscribers.

Method 1 – Operation outside of the 1710-1850 MHz band

All of the tactical radios described in the NTIA and DoD reports are capable of operating over a large amount of spectrum, ranging from 1350-1850 MHz for current systems to 1350-2690 MHz for new systems. However, in it's report, DoD states that MSE systems rarely have access to spectrum outside of 1350-1390 MHz and 1710-1850 MHz and that the DWTS systems typically use the 1350-1390 MHz, 1432-1435 MHz, and 1710-1850 MHz bands. Assuming co-channel sharing is not feasible given the operational and coverage requirements of both IMT-2000 and the military systems, we must find a comparable amount of suitable spectrum in which DoD could operate.

Additional Frequency Bands:

1) **1240-1350 MHz** - The tuning range of the radios could be extended on the lower end to include 1240-1350 MHz. It appears that current operations in this band are similar to operations in the adjacent 1350-390 MHz band and should therefore be compatible with use of the band by tactical relay radios.
2) **2200-2290 MHz** – This band is allocated for Government use on a primary basis for Fixed, Mobile, Space research, Space Operations, and Earth Exploration Satellite. Satellite allocations are for space-to-Earth and space-to-space use. The band is already used for some fixed microwave systems and tactical radio systems should also be a compatible use.

3) **2700-3600 MHz** – This frequency range is allocated for various radiolocation and radionavigation operations. Extending the tuning range to include 2700-3600 MHz would provide access to a wide range of spectrum where compatible operations should be possible.

Method 2 – In Band Sharing

In band sharing may be possible if it can be arranged in a way that ensures interference-free operation for both the military systems and the IMT-2000 systems. Considering that IMT-2000 capacity requirements will be less in rural areas than in urban and suburban areas, it should be feasible for an IMT-2000 system satisfy service requirements using less channels in these rural areas. Accordingly, assuming that an IMT-2000 operator is licensed to use sufficient spectrum to provide multiple channels (the actual number of channels required would depend on the technology deployed) it is likely that the operator could satisfy customer requirements in rural areas using less than it's full compliment of channels during periods when tactical radio systems are operating. To facilitate such an arrangement, the tactical systems would be authorized to use certain portions of the spectrum, arranged in such a way as to ensure that each IMT-2000 would retain access to some of its channels. Under this arrangement, it may also be feasible for tactical radio systems to use the corresponding channel in the 2110-2165 MHz band, which is currently only available for non-government use.[1] An example of one such arrangement is shown in Figure A.

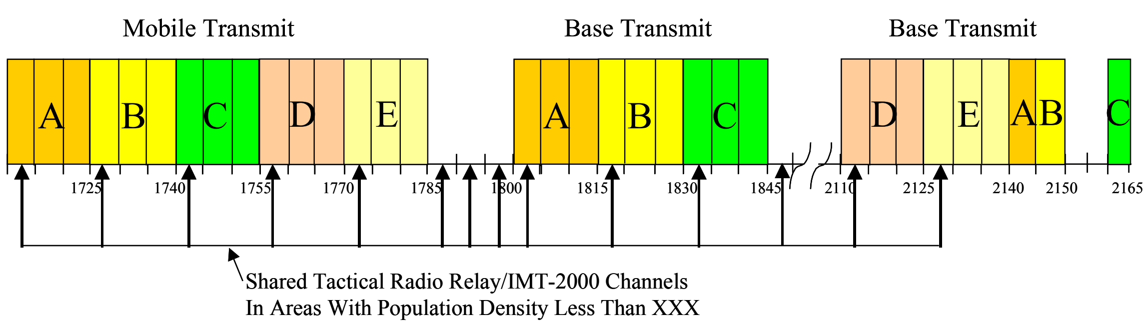

Figure A
Sample Frequency Sharing Arrangement

Additional study on adjacent channel interference is necessary to ensure compatibility of the IMT-2000 and tactical radio relay systems in order to validate the feasibility of this method.

It is likely that a combination of methods 1 and 2 could be used to address the operational requirements of tactical radio relay systems. Under this arrangement, tactical radio relay systems would have access to shared channels in areas where capacity demand for IMT-2000 services would be expected to be limited due to a lower population density. Such an arrangement should provide necessary capacity for each of the systems in the areas where demand is expected to be

[1] In such a case provisions will have to be made to take into consideration current incumbent users.

greatest. That is, for tactical radio relay systems in remote areas, where the largest scale training exercises would be expected to occur and for IMT-2000 in urban and suburban areas where higher population density will require the highest system capacity.

It is necessary to further define the areas where frequency sharing will occur.

Industry Working Group
on Air Combat Training Systems

Report

Evaluation of Sharing between International Mobile Telecommunications (IMT) 2000 Technology and Air Combat Training Systems in Band 1755-1850 MHz

Chair: Michael Lynch

21 February 2001

Executive Summary

Proposals for Spectrum Sharing with Air Combat Training Systems (ACTS)

The analysis of sharing feasibility between ACTS and IMT-2000 began with an analysis of the situation involving current systems. Those systems are the Tactical Aircrew Combat Training System (TACTS) and Air Combat Maneuvering Instrumentation (ACMI). These systems, while in use today, are scheduled to be replaced by the Joint Tactical Combat Training System (JTCTS).[1] During discussions, DoD participants indicated that some people in the military are questioning the wholesale replacement of the existing systems with JTCTS. However, there does not appear to be an operational or technical reason for not proceeding with replacement.

The first sharing methodology considered was band segmentation (Appendix A). While segmentation appears viable for sharing with JTCTS, it is not viable for sharing with TACTS/ACMI due to their fixed channel arrangements. Sharing by band segmentation with JTCTS could be achieved by:

- JTCTS operating in narrow band segments over land in spectrum used as guardbands by IMT-2000. During discussions DoD participants indicated that, while there was no restriction preventing them from using the wideband channels over land, the narrow band channels should be fully sufficient over the Continental U.S.
- Making the JTCTS receivers more efficient by limiting the passband to be equal to the transmitter bandwidth. There was no indication during the meetings that limiting the receiver passband would not be feasible.

A further area for investigation involves closer examination of the geographical separation required for co-channel sharing. A nominal distance of 400 km is given for all systems and all range areas.[2] This could be examined on a range by range basis. Additionally the data contained in a report cited should be examined to determine the sharing relationship between JTCTS and GSM-1800.[3]

In addition, potential relocation bands should also be examined. During the meetings, DoD participants indicated that, as with 3G, the Air Combat Systems are mobile systems and spectrum below 3 GHz is most suitable.

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[1] DoD IMT-2000 Technical Working Group Interim Report, p E-1

[2] ibid, p 5-3

[3] ibid, footnotes 10 & 11, p E-5

APPENDIX A: Possible Band Segmentation to Support ACTS/JTCTS Sharing with IMT-2000

Industry-Government 3G Spectrum Committee
Air Combat Training Systems Working Group

Contribution

Title: Possible Band Segmentation to Support ACTS/JTCTS Sharing with IMT-2000

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Date: January 30, 2001

Document Summary:

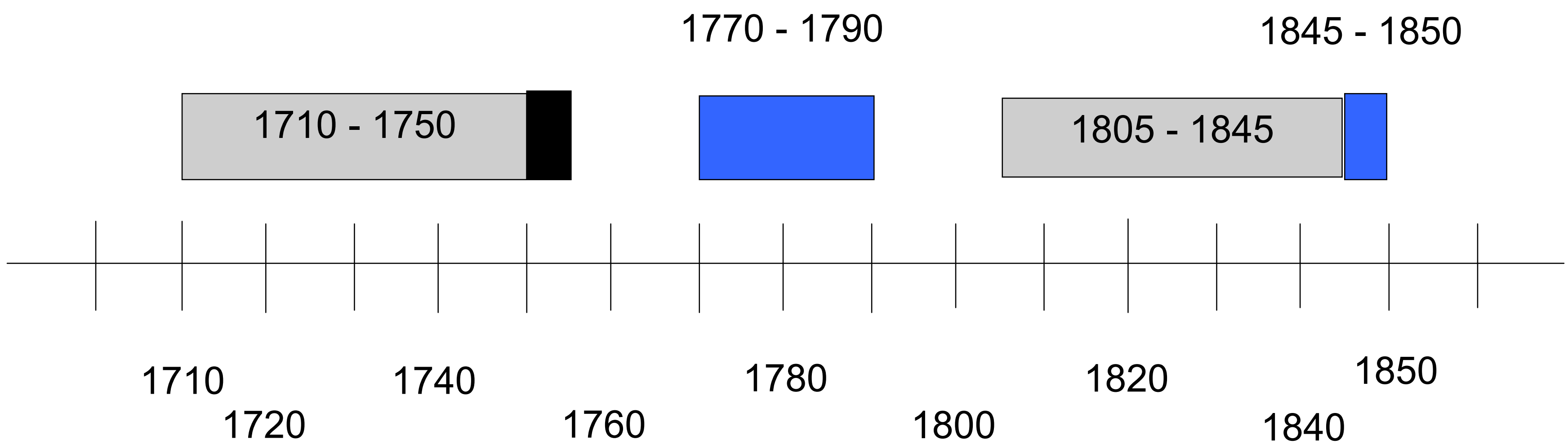
At the January 16 meeting of this working group a general discussion was held regarding the spectrum requirements for ACTS. During those discussions it seemed that spectrum sharing with the JTCTS by IMT-2000 should be possible provided that two channels were available for the JTCTS.

The attached diagram depicts a possible segmentation of the 1710 – 1850 MHz band with JTCTS utilizing two of those segments. This segmentation presumes that a decision is made to accommodate IMT-2000 FDD operations in two segments of that same band. It also presumes that JTCTS would replace all current ACTS systems (TACTS/ACMI). One of the JTCTS channels, 1845 – 1850 MHz, is located in what could become a guard band between IMT-2000 and PCS.

Recommendation and Notes of Importance:

That the ACTS Working Group discuss the attached possible band segmentation with a view to deciding the viability of sharing between JTCTS and IMT-2000.

Possible band segmentation of the 1710 - 1850 MHz band to support ACTS/JTCTS



Industry Working Group
on 2500-2690 MHz

Report

Evaluation of Sharing between International Mobile Telecommunications (IMT) 2000 Technology and Systems in the Band 2500-2690 MHz

Chair: Cecily Cohen
Paul Sinderbrand

21 February 2001

Executive Summary

The 2500-2690 MHz Working Group met on December 19th, January 16th, January 31st and February 14th. The Working Group reviewed the November 15th FCC Interim Report on the 2500-2690 MHz band to identify areas to be addressed or further developed in the FCC Final Report, scheduled for release in March 2001. The two primary issues to be studied by the group were the possibility of sharing the band among incumbent and 3G users and the technical issues raised by possible relocation of incumbents. The group agreed with the conclusion of the FCC Interim Report that co-channel sharing between incumbent systems and 3G would not feasible, as both are expected to be ubiquitously deployed. No consensus was reached about the possibility of segmenting the band for 3G services and relocating incumbent systems.

At the first meeting, the Working Group identified five main areas for further exploration:

(1) What is the level of build out for incumbent systems in the 2500-2690 MHz band? What is the future planned build out by incumbent users?

(2) What separation distances and/or guardbands are necessary to avoid interference?

(3) What would interference from incumbent systems to 3G systems be?

(4) What are candidate bands for relocation?

(5) What are appropriate attributes for relocation spectrum?

<u>Current and Planned Deployments in the 2500-2690 MHz Band</u>

The group attempted to determine the level of current deployments for MDS and ITFS incumbent systems in the 2500-2690 MHz band. It was noted that it was unclear whether the licensing information included in the FCC's Interim Report reflected only constructed stations or included conditionally licensed but unconstructed stations and that information regarding constructed facilities would be helpful in determining relocation costs and quantifying the economic and technical difficulties of relocation. However, it was also noted that because incumbents are in the process of deploying new two-way facilities, an examination of current usage would not fully address the economic and technical difficulties of relocating. It was agreed that an examination of planned deployments in the band would also need to be undertaken, and an assessment made of the economic and technical difficulties that would be caused to incumbents' future use of the band by any relocation.

The group identified an FCC database that lists transmitters currently existing in this band. However, the group acknowledged that it is still difficult to gain a full understanding of uses within the band as there are multiple licensees in overlapping service areas using complex leasing arrangements and future planned uses are not captured in this database. Some participants felt that the symbiotic relationship between MDS operators and ITFS licensees made the task of quantifying uses in the band difficult or impossible, while other participants felt that a general assessment of uses in the band could be extrapolated from some sample areas.

Towards this end, one contribution was submitted to the group that examined the MDS and ITFS licenses in the Pittsburgh metropolitan area and the Austin, Texas market as an example of current uses in the 2500-2690 MHz (Appendix A). The contribution found that more than half of the capacity licensed to ITFS operators in those markets was leased to MDS operators and extrapolated that this was typical of the band. Some participants in the working group disagreed with the conclusion that these examples were representative of the whole band, noting that in some markets all or most ITFS channels are used for ITFS programming. In its Interim Report, the FCC concluded that "most ITFS licensees lease excess capacity to MDS operators", however, it was noted that the FCC did not reach any findings with regard to how much spectrum capacity was actually being leased for the provision of commercial services. It was noted that in markets where channels are predominantly licensed and operated by ITFS, the systems tend to be analog for funding reasons.

The working group was unable to agree on any conclusion regarding the current or planned uses of the 2500-2690 MHz band.

Interference and Sharing

The working group concluded that co-channel sharing would not be possible due to interference considerations. Unacceptable interference would be caused to incumbent systems from 3G operations and to 3G systems from incumbent operations. While the FCC Interim Report evaluated interference from 3G into incumbent systems, it was noted that it did not assess the interference that would be caused to 3G from the continued operations of MDS/ITFS. The group felt that the Final FCC Interim report should include additional information on interference from incumbent systems into 3G. A contribution was submitted for consideration at the February 14th meeting of the working group that examined the co-channel interference impact of MDS/ITFS systems on 3G systems and concluded that significant geographic separation between the two systems would be required to avoid interference to the 3G system (Appendix B).

To the extent that band segmentation is considered as an option, concerns about adjacent channel interference would arise. The group did not conduct any analysis of adjacent channel interference, nor did it determine how much guard band might be required between neighboring systems. This analysis should be conducted if band segmentation is considered as an option for accommodating 3G in the band.

Relocation Spectrum

The working group attempted to address the questions of what attributes would be appropriate for relocation spectrum for incumbents and what bands could potentially be available for relocation spectrum. With respect to the appropriate attributes of relocation spectrum for incumbents, the group agreed that comparable spectrum would be needed for incumbents. The group was unable to reach agreement on how much spectrum would be required for relocated incumbents. It was noted that fixed services generally can be accommodated in bands above 3 GHz, but representatives of the MDS/ITFS community disagreed. The group was not able to resolve this dispute, and postulated that this information would likely be presented to the FCC in response to its Notice of Proposed Rulemaking. The working group did not agree on candidate frequency bands for relocation of incumbents.

Other

The working group received a contribution on the regulatory status of the 2500-2690MHz band, proposing that the FCC consider granting licensees in the band the additional flexibility to provide mobile services. The participants in the working group were unable to agree on the technical or regulatory feasibility of this recommendation. The working group concluded that this question was outside the scope of the group's largely technical work and that the issues raised by this contribution would best be discussed in the context of the FCC's rulemaking.

APPENDIX A: A business case for 3G entry into the 2500-2690 MHz band

Industry-Government 3G Spectrum Committee
Industry Working Group on 2500-2690 MHz

Contribution

Title: A business case for 3G entry into the 2500-2690 MHz band.

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Summary:

This document provides some additional views on the incumbent systems and wireless businesses within the 2500-2690 MHz band and proposes that 3G entry into the band should be considered in light of both the current business posture of the incumbent service providers, and trends in regulation and technology. It is recommended that 3G entry should be permitted in two mutually supportive ways: 1. On a shared basis where incumbent license holders may mix 3G mobile and fixed wireless access (FWA) within a cooperative infrastructure; 2. On an accommodation basis where incumbent ITFS operators may transfer channel access to 3G operators if they are accommodated by relocation or functional replacement, or through additional aggregation, disaggregation and transfer of the current 6 MHz channels in the band that could be allowed under further liberalization of recent FCC rulings. Such entry of 3G should be permitted notwithstanding any reallocation or rulemaking affecting the other bands being considered for 3G.

Background and Discussion:

From a technical perspective, the 2500-2690 MHz band should be considered prime spectrum for mobile applications due to the physics of propagation at these frequencies.

The ability to practically support mobile applications begins to diminish dramatically above about 3 GHz. Meanwhile, the ability to provide fixed access services can be accommodated in higher bands, as well as with alternative technologies that cannot be considered for mobile applications (wireline and fiber). Yet, the current incumbent operations within the US are almost exclusively fixed point-to-point or point-to-multipoint (MDS, MMDS, ITFS).

From a business and regulatory perspective, the incumbent users and supporting industry within this band have undergone major changes during the past 10 years. In short, the FCC, the license holders and the industry have participated in a rapidly evolving set of regulatory and business model changes that have permitted stepwise introduction of commercial digital video (Wireless Cable) and commercial two-way FWA broadband services. Because about 2/3 of the band is allocated and licensed to ITFS operators, the business case for these commercial enterprises depends on the commercial operator's ability to leverage and lease the "excess capacity" of the ITFS license holders within the intended market, as allowed by the FCC. Notwithstanding these arrangements, most of the past business models, primarily Wireless Cable, have failed to produce a viable, growing industry that would justify continued, exclusive dominance of the band. Furthermore, the ITFS operators have already set the precedent for "bartering" excess capacity to commercial users to the point where the majority of capacity in their channel licenses has been transferred to commercial operators. For example, research of current ITFS carriers in the Pittsburgh metropolitan area (BTA 350) reveals the following relationships.

Licensee	**Call Sign**	**Facility ID**	**ITFS Channels**	**Airtime Royalty Agreement with:**	**Parent Corporation**
Point Park College	WND296	80561	A-group (A1-A4)	American Wireless Systems	Data Not Available
Network for Instructional TV, Inc.	WHR525	48320	B-group (B1-B4)	Atlantic Microsystems	MCI WorldCom
Mon Valley Education Consortium	WNC484	43457	C-group (C1-C4)	CAI Wireless Systems	MCI WorldCom
La Roche College	WND296	81039	D-group (D1-D4)	CAI Wireless Systems	MCI WorldCom
Hispanic Information and Telecommunications Network, Inc.	WLX537	27316	G-group (G1-G4)	Atlantic Microsystems	MCI WorldCom

Table 1. Current ITFS License holders in the Pittsburgh metro area (BTA 350)

As shown in the table above, a commercial carrier has negotiated transmission privileges in the form of airtime royalty (or lease) agreements on all of the 20 ITFS channels in the market. This information was assembled from research of the FCC paper copy files; however, the complete terms and conditions of agreements in all markets is difficult to assemble due to the methods of administration and recording of the license information.

Each lease agreement is documented separately, and each has terms and conditions that are unique to the situation. The terms and conditions appear to allow for flexible access to the ITFS channels that is determined by the subscriber load experienced by the commercial operators. Five agreements were reviewed to gain a feel for the terms and conditions; two from the Austin, TX market, and three from Pittsburgh, PA. Of the 5 air time royalty/lease agreements reviewed in this research, all the agreements provide for access to well over half the capacity of the channels licensed to the ITFS operators. Coincidentally, Pittsburgh License, Inc., a subsidiary of MCI WorldCom, also holds the majority of MDS licenses in the Pittsburgh BTA. I believe that most of the BTAs are similarly situated; i.e., the ability to provide for a single operator to gain access to most of the ITFS channel capacity is a key element of the commercial business model. In effect, the process of relocating and accommodating the ITFS licensees is already well underway, and they have been constructively moved out of the band as primary users of their allocated channels under the FCC provisions for allowing leasing of excess capacity.

The latest entry into this arena is the FWA wireless broadband providers dominated by three major players who are just now rolling out services based on the 1998 FCC Two-Way Order. These operators will provide wireless, two-way, broadband services to offices and residences. It is still too early to tell whether this business model will work any better than the previous ones. The business case for these enterprises still relies on negotiated access to large amounts of ITFS spectrum.

A large investment in infrastructure (we estimate at about $2B-$4B) has already been committed by the FWA wireless broadband industry. However, it is appears that a large portion of that investment is comprised of the purchase of licenses in the form of corporate license holders who were successful bidders in the original MMDS auctions held in 1996. It is reasonable to assume that the value of that investment would remain high, and possibly even increase, if the permissible services within this band were expanded to include mobile 3G.

The International regulatory community (at the WRC) and the FCC have recently taken positions that seem to encourage use of this band for 3G. The WRC designated the band as one of 3 recommended bands. Also, under Resolution 223, the ITU Working Party 8F is studying the provision of FWA services using IMT-2000 technologies. The FCC NPRM seeks specific comment on the possibility of introducing advanced wireless systems into the band where both FWA and next generation mobile could coexist in a flexible arrangement. It appears that both the ITU and the FCC have taken a long-range view of the destiny of this band, and they have recognized that the ultimate destiny of the band will be to host mobile services, as it can do so well.

I also believe the FCC's use of the terms "advanced wireless systems" and "flexibility" is no accident. The future of wireless air interface technology is already beginning to take on adaptive, automated network management features. Adaptive bandwidth, asymmetric links, and multi-mode, multi-band base stations are all becoming reality. It seems that the FCC is demonstrating some considerable vision in addressing the implications of these technology trends. On the one hand, the FCC was compelled to apply the existing conservative standards and criteria for maintaining distance between service providers in the analyses provided in the 15 November FCC Interim Report. The criteria and coordination procedures reflected in that report are based on technologies that are rapidly disappearing from the band, and soon may cease to exist. However, rather than relying on band segmentation and very conservative, outdated interference analysis assumptions (e.g., 45 dB C/I) to keep competing service providers apart, the future advanced wireless systems are more likely to be characterized and designed as a "cooperative infrastructure". The FCC has signaled their enthusiasm and asked for comment on this view of the future through recent proceedings, conferences, NPRM's and NOI's dealing with software defined radios, secondary markets and advanced wireless services (including 3G). The first step toward that vision is to provide a regulatory environment and access to spectrum wherein development of such a multifunction, cooperative infrastructure for both fixed and mobile services is to the mutual benefit of customers, industry and government, alike. The current state of the 2500 – 2690 MHz band makes it a reasonable choice.

Given this view of both the technical and business trends, does it make sense to lock in exclusive access for an immature, unproven and potentially relocatable FWA industry, thereby passing up the opportunity to allocate 3G mobile services in the band? I believe that the answer from this Committee should be no; it does not make sense.

Recommended actions:

The FCC and industry have an opportunity to turn the past history of rapid, reactive changes in this band to an advantage. By recognizing that there is no strong, mature incumbent, the FCC can create the host environment for true multi-mode, multifunction technologies to flourish and best serve the customer. They can do this by continuing the trend of regulatory accommodation that began with the creation of analog ITFS, then MMDS and subsequent steps that were taken to change the permitted services and functions without asking for the licenses back. By expanding the permitted services and allowing more unencumbered business arrangements to be implemented by the existing license holders, the FCC can create a win-win scenario for customers and operators. I recommend that the Industry-Government 3G Spectrum Committee provide the following recommendation to the FCC:

Regardless of additional 3G allocations in any of the other bands under consideration, we recommend that the FCC:

1. Change the 2500 – 2690 MHz band allocation and allow all MMDS/MDS/ITFS license holders to operate 3G wireless systems within their service areas, or BTA's. Permission for conversion to 3G operations is predicated on accommodating any existing

FWA subscribers so that they do not suffer diminished service. Such accommodation does not need to be accomplished through wireless means.

2. Lift the remaining limitations and restrictions on ITFS leasing of excess capacity such that the ITFS licensee can lease, or otherwise transfer, 100% of the access for any channels, or part of a channel, to any 3G or FWA operator. Provide for protection of the ITFS functions by demanding that conversion of ITFS licensee rights to 3G or FWA operations is predicated on accommodating any existing ITFS subscribers so that they do not suffer diminished service. Provide for protection of incumbent FWA operators such that permission for conversion to 3G operations is predicated on accommodating any existing FWA subscribers sharing the market so that they do not suffer diminished service. Such accommodations do not need to be accomplished through wireless means.

APPENDIX B: Interference to 3G Systems from ITFS/MDS Systems Sharing the Same Frequencies

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Introduction and Summary

The purpose of this paper is to analyze the potential for interference to proposed 3G systems from ITFS/MDS systems sharing the same frequency of operation. This analysis examines all of the proposed IMT-2000 standards for which interference thresholds were available, based on the technical specifications set forth in the January 25, 2001 draft Report of the 3G Characteristics Group of the Industry/Government Informal Working Group (the "3G Characteristics Report").[1] The analyses calculate the required separation distances between proposed 3G base and mobile units and ITFS/MDS base stations and customer premise units (response stations). As summarized in Appendix 1, substantial separation from MDS/ITFS systems is required in order for 3G systems to operate on a cochannel basis without interference.

Analysis

Table 1 to the 3G Characteristics Report defines two interference thresholds for base and mobile 3G units. Threshold 1 is defined by the received signal level being at sensitivity, with an interference-to-noise equal to –6 dB, resulting in a 10 percent loss in the range of the system. The received signal level being 10 dB above the sensitivity point with the signal-to-noise ratio resulting in a bit error rate of 10-3 defines threshold 2. These thresholds were not defined for some categories of 3G technologies and therefore calculations were not performed in all cases.

Using these interference thresholds, the separation distance between 3G receivers and ITFS/MDS transmitters necessary to avoid interference can be calculated. For purposes of the calculations, 3G mobile units were assumed to utilize a receive antenna with unity gain and hub antennas were assumed to utilize an antenna with 17 dBi gain.

ITFS/MDS base stations and response stations (subscriber CPE) operate with a variety of power levels. The maximum power level allowed by the FCC for stations that utilize an omnidirectional transmit antenna is 2000 watts EIRP in a 6 MHz bandwidth. In those situations where the station is transmitting an analog signal, this is measured as peak power, while for digital transmissions it is measured as average power. Most single cell ITFS/MDS systems, the most prevalent type to date, operate with EIRP levels between 500 and 2000 watts. Individual cells within cellular systems will operate with a

[1] There is no reason to believe that the results would be significantly different for the cases where interference thresholds were not included in the 3G Characteristics Report.

wider range of power levels, depending on the number of cells, the service area of the particular cell, and the propagation characteristics of the market. Therefore, three power levels, 2000, 500 and 100 watts EIRP, were considered in the analysis.

ITFS/MDS response stations (the CPE) also operate with a variety of power levels and bandwidths. The maximum power level allowed by the FCC is 2000 watts in a 6 MHz bandwidth. As the bandwidth is reduced or increased, the maximum power level of the upstream transmitter is adjusted based on equivalent power spectral density. For purposes of this analysis, a typical power level of 668 watts EIRP in a 2 MHz bandwidth was utilized.

Attached as Appendix 1 is a table showing the separation distance required between an MDS/ITFS transmitter and each proposed 3G technology. These calculations assume an unobstructed electrical path to the radio horizon limit of 161 kms. Calculations resulting in separation distances beyond the radio horizon were limited to 161 kms. Also, the worst case geometry resulting in bore sighted conditions between the transmit and receive antenna was assumed. No cross polarization discrimination was considered since ITFS/MDS systems use both horizontal and vertical polarization liberally to maintain isolation with adjacent markets. In addition, these studies did not consider the effects of multiple ITFS/MDS radiators within a market. Note however that in all markets there will inevitably be multiple response stations (CPE) operating simultaneously and that in multicell markets, multiple downstream transmission may be occurring on the same frequency at the same time. A more detailed analysis accumulating the signal levels generated by these multiple radiators was not conducted in light of the compelling results when even a single radiator is considered.

Interference to 3G Mobile Receivers

As the results show, interference threshold 1 for mobile 3G receivers is only met when the receiver is isolated from the ITFS/MDS base or CPE transmitters using the radio horizon for separation. The required separation distance is always beyond the radio horizon and is therefore for purposes of Appendix 1 is limited to the defined radio horizon distance of 161 kms.

Likewise, for a majority of the cases analyzed based on interference threshold 2 the separation requirement for mobile 3G receivers remains at or very close to the radio horizon. However, when the ITFS/MDS base station power is lowered to 100 watts EIRP, the separation distance is reduced to 66 kms for CDMA 2000 1X. Note, however that this power level of 100 watts is only likely to be employed by MDS/ITFS multicell systems. Therefore, as a practical matter it will be necessary to consider the accumulation of signals from multiple MDS/ITFS cells and greater separation will be required to protect the 3G system.

Interference to 3G Base Station Receivers

The results show for all cases at interference threshold 1 that the level of interference into 3G hubs requires separation distances equal to the radio horizon. When the interference threshold is relaxed to threshold 2, certain 3G technologies will allow a 3G base station to operate within 102 kms or a 100 watt MDS/ITFS base station.

Conclusions

These calculations prove conclusively that cochannel frequency sharing between 3G and ITFS/MDS systems is not a practical solution. MDS/ITFS systems are operating in most markets across the country, and the required separation distances would only permit 3G systems to operate without interference in the most rural areas.

Appendix 1 – Interference to 3G Receivers from ITFS/MDS Transmitters

3G System Parameters			*ITFS/MDS Base Station (2000 Watts)*				*ITFS/MDS Base Station (500 Watts)*				*ITFS/MDS Base Station (100 Watts)*			
Protected Receiver Type	Modulation Type	Bandwidth (MHz)	Bandwidth (MHz)	EIRP (dBm)	Separation 1 (kms)(1)	Separation 2 (kms)(2)	Bandwidth (MHz)	EIRP (dBm)	Separation 1 (kms)(1)	Separation 2 (kms)(2)	Bandwidth (MHz)	EIRP (dBm)	Separation 1 (kms)(1)	Separation 2 (kms)(2)
Mobile	CDMA 2000 1X	1.25	6	63	161	161.0	6	57	161	148.2	6	50	161	66
	CDMA 2000 3X	3.75	6	63	161	161.0	6	57	161	161.0	6	50	161	72
	UWC-136	0.03	6	63	N/A	N/A	6	57	N/A	N/A	6	50	N/A	N/A
	UWC-136	0.2	6	63	N/A	N/A	6	57	N/A	N/A	6	50	N/A	N/A
	TD-CDMA	5	6	63	161	161.0	6	57	161	161.0	6	50	161	105
	W-CDMA	5	6	63	161	161.0	6	57	161	161.0	6	50	161	74
Base Station	CDMA 2000 1X	1.25	6	63	161	161.0	6	57	161	161.0	6	50	161	105
	CDMA 2000 3X	3.75	6	63	161	161.0	6	57	161	161.0	6	50	161	102
	UWC-136	0.03	6	63	161	161.0	6	57	161	161.0	6	50	161	115
	UWC-136	0.2	6	63	161	161.0	6	57	161	161.0	6	50	161	118
	TD-CDMA	5	6	63	161	161.0	6	57	161	161.0	6	50	161	161
	W-CDMA	5	6	63	N/A	N/A	6	57	N/A	N/A	6	50	N/A	N/A

(1) Separation required to limit loss in range of 3G system to 10%.

(2) Separation required to keep desired signal 10 dB above sensitivity and S/(I+N) for a 10^{-3} BER.

Attachment VI: 3G Association Group Distribution List

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