Department of Defense
IMT-2000
Technical Working Group

Interim Report

Investigation of the Technical Feasibility of Accommodating the International Mobile Telecommunications (IMT) 2000 Within the 1755 – 1850 MHz Band

27 October 2000

EXECUTIVE SUMMARY

Advances in wireless and digital technologies have led to the development of Third Generation (3G) mobile wireless services, sometimes referred to as International Mobile Telecommunications for the Year 2000 (IMT-2000). Recently, the World Radiocommunication Conference 2000 (WRC-2000) identified several frequency bands that administrations are urged to considered when developing IMT-2000 mobile services. The frequency bands identified by WRC-2000 to support additional mobile services include 698-960 MHz, 1710-1885 MHz, and 2500-2690 MHz.

The United States is seeking to develop IMT-2000 services as rapidly as possible. In the US, interest in IMT-2000 has focused on the two higher frequency bands for further study. In the frequency band 1710-1885 MHz, 1755-1850 MHz is allocated to Government Fixed and Mobile Services. Without question the largest single user of the band is the Department of Defense (DoD). This report presents the interim results of the technical assessment of sharing or segmenting the 1755-1850 MHz band with IMT-2000 and its implications to major DoD systems. The final report will assess the critical operational and cost implications of accommodation of IMT-2000 in the 1755-1850 MHz band. Use of the 2500-2690 MHz frequency band is managed by the Federal Communications Commission (FCC).

The 1755-1850 MHz frequency band supports a wide variety of DoD systems crucial to the warfighter's ability to successfully perform missions. Although the DoD has over one hundred nomenclatured systems that employ this spectrum, this interim assessment addresses only selected major systems. The major functions supported include tracking, telemetry, and commanding (TT&C) of DoD space systems, transportable tactical radio relay communications, air combat training, fixed radio relay communications, and mobile video control links. Specific systems include, but are not limited to, the Space Ground Link Subsystem (SGLS) which provides space systems TT&C, Mobile Subscriber Equipment (MSE) and Digital Wideband Transmission System (DWTS) which support tactical communications, and the Air Combat Training Systems (ACTS) and the Joint Tactical Combat Training System (JTCTS) used to support air combat training.

The DoD has formed three working groups, Technical, Operational, and Cost, to assess the impact of proposals to reallocate 1755-1850 MHz to shared or non-government operation. While the working groups are performing in close coordination, the initial assessments are being made primarily by the Technical Working Group (TWG). This report documents an electromagnetic compatibility (EMC) assessment of only selected major DoD systems and possible IMT-2000 systems. Schedule limitations prevented detailed consideration of all DoD systems; however, certain critical DoD systems were addressed. Many IMT-2000 technical parameters are yet to be finalized; consequently, notional IMT-2000 parameters were coordinated with the FCC and were used in the assessment.

The limited EMC assessment considered two-way interactions between candidate IMT-2000 systems and SGLS, tactical radio relay systems, air combat training systems, and tactical weapons control systems. Full band sharing was considered, as were possible band segmentation plans. This report documents the following possible sharing options:

- Full band sharing of the 1755-1850 MHz spectrum
- Band segmentation: 1755-1805 MHz retained for Federal Government use, 1805-1855 MHz reallocated for commercial use
- Phased band sharing: IMT-2000 phased over 1755-1790 MHz, with restrictions on IMT-2000 systems

The results of the full band sharing EMC assessment indicates that significant undesired interactions may occur both to and from DoD systems. Distance separations needed to preclude interference can be substantial, particularly in the case of airborne platforms. SGLS receivers represent a particular problem, as aggregate IMT-2000 emissions may quickly degrade needed link margins.

Band segmentation plans as a means of sharing produced mixed results. Reallocation of 1805-1855 MHz to non-government services may have a major impact on systems performance yet to be determined, although in some cases it appears technically feasible. Phased band sharing with coordination requirements and operational restrictions on IMT-2000 systems seems theoretically viable from the DoD perspective for most DoD systems, but may not be operationally acceptable to the IMT-2000 community. However, for the SGLS receivers this option will quickly become problematic.

These results are based solely on the technical assessment. This effort only analyzed the interactions between one DoD system in operation at any given time on a one-to-one basis with IMT-2000 systems. In order to determine the full possibility of sharing, operational impacts must be determined. Further, DoD operational risks associated with any band segmentation approach must be assessed to determine if band segmentation will enable DoD to conduct operations in a satisfactory manner. Operational and cost risks associated with undesired interactions will be assessed in the next phase of the DoD assessment.

Some possible means to mitigate potential interference were identified and are presented in the report. In some cases mitigation measures would be applied to either IMT-2000 systems or to DoD systems. In other cases cooperative measures would be necessary. In all cases, the operational risks associated with each possible mitigation measure will have to be addressed in the next phase of the DoD assessment.

1.0 INTRODUCTION

1.1 BACKGROUND

In recent years mobile wireless telecommunications systems have experienced a growth that is matched by few other technologies. Large-scale mobile wireless common carrier services began with cellular systems, sometimes referred to as first-generation systems. Subsequently, second-generation systems, Personal Communications Services (PCS), provided many enhancements to cellular-type service. Advances in several technologies have led to the development of third-generation (3G) services, sometimes referred to as International Mobile Telecommunications for the Year 2000 (IMT-2000). Recently, the World Radiocommunication Conference 2000 (WRC-2000) identified several frequency bands that administrations are urged to consider when developing additional mobile services. Identifying common frequency bands will enhance economies of scale and promote universal mobile telecommunications services.

The frequency bands identified by WRC-2000 to support additional advanced mobile communication services include 698-960 MHz, 1710-1885 MHz, and 2500-2690 MHz. In the US, study is required on the two higher frequency bands. In the 1710-1885 MHz frequency band, 1755-1850 MHz is allocated to Government Fixed and Mobile Services. Many Federal Departments make substantial use of the 1755-1850 MHz frequency range for fixed and mobile operations. Without question, the largest single user of the band is the Department of Defense (DoD).

For the DoD, 1755-1850 MHz supports a variety of large and critical systems, as well as many important, long-established local users and systems in development. The major functions supported in the band include tracking, telemetry, and commanding (TT&C) of DoD space systems, transportable tactical radio relay communications, air combat training, fixed radio relay communications, and mobile video control links. Specific systems include, but are not limited to, the Space Ground Link Subsystem (SGLS) which provides satellite TT&C, Mobile Subscriber Equipment (MSE) and the Digital Wideband Transmission System (DWTS) which support tactical communications, and the Air Combat Training Systems (ACTS) and the Joint Tactical Combat Training System (JTCTS) used to support air combat training.

Federal Departments have been asked to examine their use of the 1755-1850 MHz frequency band and to assess the prospects for sharing spectrum with IMT-2000 systems. The DoD is complying with this request by identifying all DoD systems that operate in the band of interest, assessing the technical feasibility of sharing, examining the operational impact of sharing and/or relocation, and quantifying cost issues associated with sharing and/or relocation. This interim report presents an initial assessment of the technical issues associated with sharing by examining electromagnetic compatibility (EMC) issues associated with selected DoD systems and several candidate IMT-2000 systems. While IMT-2000 services will ultimately be deployed worldwide, the focus of this effort was primarily sharing issues in the US. Further technical assessments and discussions of operational and cost issues will be presented in subsequent reports.

1.2 OBJECTIVE

The objective of this effort was to perform an initial assessment of the technical feasibility of sharing and identify EMC issues between possible IMT-2000 mobile wireless systems and selected DoD systems that operate in the 1755-1850 MHz frequency band. This study is designed to be a part of a larger effort involving separate operational and cost analyses.

1.3 APPROACH

The overall approach to this task was fundamentally similar to the basic approach used in standard EMC assessments. Technical parameters for the radio frequency (RF) systems were identified, possible operational scenarios were defined, desired and interfering signal levels were predicted at the receivers of interest, and predictions were made with respect to the potential for undesired interactions. If undesired interactions were predicted, then required distance and/or frequency separations to avoid interference were calculated. Also, in those cases where interference was predicted, possible means to mitigate interference, beyond frequency/distance separations, were identified. Unique aspects of individual interactions are discussed in the individual assessments.

Specific technical parameters of IMT-2000 systems were required for the EMC assessments. However, at the time this assessment was performed, IMT-2000 hardware was not in production for the US market. Consequently, it was necessary to develop parameters from the technical literature, to consider selected aspects of existing wireless mobile systems, and to calculate certain characteristics using communications theory. The basis for the final parameters used in the assessments was a Federal Communications Commission (FCC) document presenting notional characteristics for the various technologies that may be used to implement IMT-2000. Minor modifications to some of the FCC-postulated parameters were made following discussions between staff supporting the FCC and technical staff supporting the DoD EMC assessment effort. The IMT-2000 technical parameters are presented in some detail in the *Analysis* section.

The DoD performed an extensive survey of operational commands, program offices, support facilities, and acquisition documentation to identify RF systems that operate in some or all of the 1755-1850 MHz band. Several hundred systems were identified, and basic information on these systems was compiled for use in this study. Individual EMC assessments of all of the DoD systems was not possible within the available time. For this initial effort several major critical systems were selected for EMC assessments to scope the extent of interference issues, to initiate a dialogue between government and industry regarding sharing options, and to begin examining possible interference mitigation measures. The DoD systems addressed in this report are the SGLS, transportable tactical radio relay radios, ACTS, JTCTS, and several precision strike weapons. EMC assessments of additional DoD systems will proceed following the completion of this interim effort.

For the DoD systems considered, extensive technical and operational data was gathered. This information included system waveforms, transmitter parameters, system losses, antenna patterns, antenna pointing angles, siting data, receiver selectivities, and receiver performance criteria. In addition such operational information as geographical locations, link lengths, and aircraft altitudes was also gathered. Planned system upgrades were considered when available technical data was sufficient to support an EMC assessment.

Having gathered notional technical data on IMT-2000 systems and actual data on DoD systems, analysts assessed the technical feasibility of sharing in the 1755-1850 MHz band. Several sharing scenarios were considered, and the assessment sharing scenarios were conducted based on the interference analysis between systems on a one-to-one basis, and no consideration was given to interactions among multiple systems. In the first scenario, complete frequency sharing of the band was considered; that is, it was assumed that IMT-2000 systems could operate anywhere in the band, and DoD systems would operate as they do now. Also, two band segmentation plans were considered. In the first segmentation plan, 1805-1850 MHz was hypothetically reallocated to non-government use, and 1755-1805 MHz remained available for operation of government systems. In the second plan, phased sharing occurs where 1710-1755 MHz would be available for IMT-2000 immediately, and as network capacity required, 1755-1780 MHz would become available at a future date, followed by 1780-1790 MHz. In this second segmentation plan the spectrum in the band of interest would be available only for mobile-to-base links, and IMT-2000 operations within coordinated distances of relevant DoD sites would use a listen-before-transmit capability to manage frequency usage to avoid interference. Additional band segmentation plans and possible relocation options will be addressed in future efforts from an operational, cost, and technical viewpoint.

It should be noted that the technical assessments documented in this report used material presented in International Telecommunication Union (ITU) documents, documents from the European Telecommunication Standards Institute (ETSI), previous Joint Spectrum Center (JSC) reports, and other technical sources. Reference material is cited as appropriate throughout this report.

The main body of this report provides background material on the sharing issue, system descriptions of the IMT-2000 and DoD equipment considered in this initial assessment, a description of the technical approach, an identification of critical assumptions applicable to all of the technical assessments, and a discussion of the results. There are several appendixes to this document. Each appendix provides a detailed description of the DoD system(s) considered in that appendix, a description of the specific technical approach used in the associated assessment, an identification of critical assumptions made in order to complete the technical assessment, and a discussion of the results of the assessment.

2.0 SYSTEM DESCRIPTIONS

2.1 IMT-2000 SYSTEM DESCRIPTION

IMT-2000 and 3G services are the names commonly used to refer to the next-generation mobile wireless telecommunications services. The 3G family of services, and the systems that will provide them, are intended to reflect a high degree of commonality and are to be compatible with each other. These services will support mobile and fixed users employing a wide range of devices including small pocket terminals, handheld telephones, laptop computers, and fixed-receiver equipment. 3G services are envisioned to be ubiquitous throughout the globe, as available in a remote part of a developing country as they are in an urban area in a highly developed country. Seamless roaming is a key attribute. Access to services is expected to be uniform. Furthermore, the user will be able to roam from an urban setting to a suburban one into a rural setting without loss of basic services.

Consumer demand for services available at any place, coupled with the expectation of high quality, are key drivers in the effort to establish commonality and compatibility of 3G terrestrial telecommunication systems. It is estimated that by the year 2010 there will be one billion wireless subscribers worldwide on 3G networks.[1] At the present time, the worldwide penetration of wireless service is approximately 7½ percent and it is expected to exceed 30 percent by the end of the first decade of the new millennium.[2] There are over 1,300 cellular and second-generation terrestrial mobile service networks currently operating worldwide, each with a limited geographic coverage. Hence, it is easy to understand the importance of standardization in system design and service provision for 3G services if uniform services and seamless roaming are to be provided on a regional or global scale.

It is generally agreed that IMT-2000, or 3G, systems will require use of spectrum that extends beyond that already encumbered by first and second generation mobile systems. A major issue in the global debate regarding 3G system design, standards, and services that must be resolved is the amount of common or “harmonized” spectrum that will be available on a global and regional basis to support 3G systems. For ease in roaming, to help stimulate commonality in services, and economies of scale, proponents of 3G services believe it is important to identify as much contiguous harmonized spectrum to support worldwide 3G operations as is practical. This will stimulate the development of global and regional coverage of 3G systems by reducing the cost and complexity for system development, thus

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[1] United States Talking Points for WRC 2000 on IMT–2000 spectrum requirements.

[2] *Id.*

providing users with more cost-effective services. The ITU, with the support of the US, has designated 1710-1885 MHz as a frequency band suitable for the development of IMT-2000 services. The technical parameters of the IMT-2000 system used in the assessment are contained in Appendix A.

2.2 DOD SYSTEM DESCRIPTIONS

The DoD has received spectrum certification for hundreds of communications-electronics systems in the 1755-1850 MHz frequency range and operates many thousands of these systems in the US and abroad. Each of the military services has major, critical systems in this frequency band, as well as important local systems for command and control, security, telemetry, target scoring, video links, and a variety of other functions. Table 2-1 identifies some of these systems and the functions the systems perform.

Table 2-1. Examples of DoD Systems Operating in 1755-1850 MHz

System Name	Function
Space Ground Link Subsystem	Satellite telemetry, tracking, and command
AN/GRC-103	Tactical radio relay
AN/GRC-226	Tactical radio relay
AN/GRC-245	Tactical radio relay
AN/MRC-142	Tactical radio relay
AN/SRC-57	Tactical radio relay
Tactical Aircrew Combat Training System	Air combat training
Air Combat Maneuvering Instrumentation System	Air combat training
Joint Tactical Combat Training Systems	Air combat training
Weapons Control Link	Control of precision strike weapons
Land Warrior	Wireless local area network for combat troops
AN/DSQ-37	Target scoring system
Combat ID for the Dismounted Soldier	Tactical communications
Intrusion Detection System	Perimeter security
Robotics Control System	Wireless remote control

Within the time and resources available for this assessment it was not possible to address all of the DoD systems certified to operate in 1755-1850 MHz. Several critical systems were selected for the assessments to help establish the scope of compatibility issues associated with the possible sharing of the frequency band. Overviews of these systems are provided below. Detailed descriptions and the technical parameters used in the assessments are presented in the associated appendix.

2.2.1 Space Ground Link Subsystem

The DoD conducts satellite operations (SATOPS) in the 1755-1850 MHz and 2200-2290 MHz frequency bands to maintain control of, and to receive health and status data on, over 120 satellites flying in both geostationary and non-geostationary orbits. The DoD SATOPS uplink functions, which include the transmission of commanding and ranging signals, are performed in the 1761-1842 MHz portion of the band. Downlink telemetry data is passed via the 2200-2290 MHz band. The Air Force Satellite Control Network (AFSCN) is a worldwide network of US Air Force ground stations and control centers which provide telemetry, tracking, and commanding (TT&C) services to DoD satellites. The AFSCN consists of two control nodes, Schriever Air Force Base, CO, and Onizuka Air Station (OAS) at Sunnyvale, CA, plus eight Automated Remote Tracking Stations (ARTS) dispersed both within and outside the US. The earth stations generally employ high-power transmitters with highly directional, tracking antennas capable of pointing to within three degrees of the horizon. The spaceborne systems use very sensitive receivers with omnidirectional antennas.

A description of SGLS spaceborne receiver operations and the associated assessment of potential interference from IMT-2000 emitters are presented in Appendix B. A description of the SGLS earth station transmitters and the associated assessment of potential interference to IMT-2000 receivers are presented in Appendix C.

2.2.2 Tactical Radio Relay

Mobile Subscriber Equipment (MSE). The MSE is a multi-band, tactical line-of-sight (LOS) radio system, more accurately described as a “system-of-systems,” because it is composed of several components, each of which are fully operational systems. The individual components that make up the MSE are dependent upon several portions of the radio frequency spectrum. The inability of any of these components to operate successfully would result in the failure of the overall system. One critical component of the MSE, the AN/GRC–226(V)2 radio, operates in the 1755–1850 MHz frequency band. It is used to connect radio access units to the node center switch of the network. Operational use plans call for 465 units per Army Corps, giving a total of 2,325 units for five Corps. The AN/GRC-226(V)2 is a digital radio that can tune to any of 4000 available channels, spaced at 125 kHz, between 1350-1850 MHz; however, due to the allocation of most of this band to other services, users rarely have access to spectrum outside of 1350-1390 MHz and 1710-1850 MHz. The AN/GRC-226(V)2 requires a 50.125-MHz minimum frequency separation between transmitter and receiver for a duplex link.

High Capacity LOS (HCLOS). The HCLOS is expected to eventually replace the AN/GRC-226(V)2 radios in the MSE for the Area Common User System (ACUS). The HCLOS radio, the AN/GRC-245(V) operates with increased spectral efficiency and higher data rates compared to the current radio. The AN/GRC-245(V) requires a 50.125-MHz minimum frequency separation between transmitter and receiver for a duplex link.

Digital Wideband Transmission System (DWTS). The DWTS consists of two components, the shore based USMC AN/MRC-142 and the ship based US Navy AN/SRC-57. DWTS is an LOS tactical radio system providing point-to-point (shore based AN/MRC-142), ship-to-ship (ship based AN/SRC-57), and ship-to-shore (AN/MRC-142 and AN/SRC-57) communications. The DWTS provides communications vital to the Commander Joint Task Force (CJTF), Commander Amphibious Task Force (CATF), Commander Landing Force (CLF), Amphibious Forces afloat, and US Forces ashore. The system provides afloat and ashore commanders with entry into the Global Command and Control System – Maritime (GCCS-M) to ensure common access to intelligence, mapping, order of battle, and logistics information. The DWTS provides data transmissions for Battlegroup (BG) planning, video tele-conferences, BG e-mail connectivity, Internet connectivity, and intra-BG telephone connectivity. DWTS provides tactical digital wideband transmissions for voice, video, and data to support landing force command elements to include Marine regiment or Expeditionary Unit and higher and Army brigade and higher.

Detailed descriptions of the tactical radio relay systems and the associated interference assessments are presented in Appendix D.

2.2.3 Air Combat Training Systems

The DoD has several systems that are used to train aircrews in air combat operations and maneuvering. The Navy and the Marine Corps use the Tactical Aircrew Combat Training System (TACTS) and the Air Force uses the Air Combat Maneuvering Instrumentation (ACMI) system, both of which are quite similar in operation. The systems are used in such training exercises as gun scoring, no-drop bombing, evasion and intercept tactics, and electronic warfare. These systems are deployed at fixed, large, generally remote sites in the US and abroad.

The systems include an Airborne Instrumentation Subsystem (AIS) which is attached to a participating aircraft. The AIS units communicate with stations of the Tracking Instrumentation Subsystem (TIS) that are distributed throughout the associated range over which the aircraft operate. The AIS/TIS interface allows for the recording of air operations, simulation of air combat events, precision location of participating aircraft, simulation of land-based anti-air weapon engagements, and operations monitoring by a master control facility. Air-ground-air and ground-to-ground communications links for these systems all operate between 1755-1850 MHz. Theses training systems are absolutely essential in maintaining the operational readiness of combat aircrews. Versions of these ranges are located in California, Nevada, Utah, Arizona, Wisconsin, Alaska, Florida, North Carolina, and South Carolina.

The DoD is currently developing an additional ACTS system, the Joint Tactical Combat Training System (JTCTS). This system has a “rangeless” capability that allows participating aircraft to engage in training exercises anywhere other properly equipped aircraft are available. That is, it is possible to perform air combat operations using only air-to-air links where event data is stored on the aircraft and used later for training and debriefing once the aircraft have landed. The system can also be configured for air-ground-air and ground-to-ground operation. This system will not necessarily replace the existing ACTS system, but it is primarily intended to permit the training of aircrews at locations removed from specially instrumented ranges.

Detailed descriptions of the TACTS/ACMI and JTCTS systems and the associated interference assessments are presented in Appendix E.

2.2.4 Tactical Weapons Links

The DoD operates a number of weapons systems where communications between a launched weapon and a controlling platform allow for the precision delivery of the weapon’s payload. The 1755-1850 MHz frequency range plays a role in the operations of several such critical systems. A classified supplement to this report contains descriptions of these systems and associated interference assessments.

3.0 ASSESSMENT APPROACH

The goal of this effort was to assess the potential for sharing in the 1755-1850 MHz frequency band from a technical perspective only. Assessments were two-way assessments in that analysts considered both interference from DoD systems to IMT-2000 receivers and interference from IMT-2000 emitters to DoD receivers. The general technical approach was to predict undesired signal power at victim receivers by considering appropriate interfering transmitter parameters, operational configurations, coupling between systems considering antenna orientations and propagation losses, and frequency-dependent rejection when appropriate. Undesired received power levels and victim receiver interference thresholds were then used to assess the potential for interference. Interference thresholds may be either interference-to-noise ratios, desired signal-to-interference plus noise ratios, or the degradation of link margins needed to sustain acceptable bit or symbol energy-to-noise power densities. Desired signal levels were either calculated or provided by system users based on their experience with the design and use of the subject system.

It was recognized that a number of the assessment parameters may not yet be finalized or may vary depending on operational configurations. Consequently parametric assessments were performed in many cases. Many of the appendixes contain either multiple figures showing variations in signal levels for different values of selected parameters or tables with multiple entries for similar reasons. Parameters that may vary include, but are not limited to, transmitter power, antenna gain, antenna pointing angles, antenna heights, data rates, receiver selectivities, and desired signal levels.

Implementation of the general technical approach had variations depending on the particular DoD systems being considered. For example, in the SGLS-to-IMT-2000 assessment, the primary SGLS sites are fixed in location. In this case, a terrain-dependent propagation model could be used to establish received signal level contours around the SGLS earth station sites for various IMT-2000 base stations and mobile units. Multiple contours are provided in Attachment 1 to reflect variations in receive system parameters and different SGLS transmit powers and antenna elevation angles.

In the case of mobile or transportable DoD systems, terrain-dependent propagation modeling was not appropriate and a smooth-earth propagation model was used. Also in these cases, this initial assessment tended to place mobile and transportable units at distance separations or altitudes that either reflected guidance from the appropriate program office or represented communications links that would be operating near minimally acceptable conditions. The latter approach is somewhat conservative and was used principally to bound the limits of sharing issues. In several cases, sharing is investigated where desired signal levels are significantly better than minimally acceptable levels. These cases are so noted in the appendixes.

Source-to-victim configurations also varied in the assessments. In some cases one-to-one assessments were performed where the principal source of interference was a single emitter of one system to a single receiver of a victim system. Examples of these cases include a single AN/MRC-142 radio to a single IMT-2000 mobile receiver (Appendix D) and a single IMT-2000 base station emitter to a single ACTS ground receiver (Appendix E). In other cases, assessments addressed many-to-one interactions. Examples of these cases include multiple IMT-2000 emitters to spaceborne SGLS receivers (Appendix B) and multiple IMT-2000 emitters to DoD aircraft participating in training exercises (Appendix E).

As reflected in the description of IMT-2000 systems, mobile wireless networks are deployed over the period of several years. When appropriate, the assessments considered the notional build-out schedule contained in Table A-7. Consideration of this schedule gives an approximate estimate of when certain systems may be affected as IMT-2000 networks are built-out in the US. These estimates are not precise and may be subject to debate but they do identify those systems particularly sensitive to large-scale network development such as airborne and spaceborne receivers.

The technical feasibility of band segmentation is also addressed in the appendixes. In general, the impact of implementing band segmentation plan 1 (only 1755-1805 MHz remains allocated for government use) becomes an operational issue. For example, is there sufficient spectrum remaining to satisfy communications requirements for multiple radio relay users or aircraft training for combat? The answer to this depends on the numbers of units needing training and operational support. Such determinations will be addressed in subsequent reports. For band segmentation plan 2, the size of the area requiring accommodation by new IMT-2000 emitters is largely defined by the assessments performed to evaluate overall sharing of the band.

The discussion above illustrates the wide variation in configurations and parameters that affect sharing predictions. This initial assessment is best suited to establish the scope of sharing considerations and to initiate a dialogue with parties interested in the 1755-1850 MHz frequency band. Such a dialogue can help refine the assumptions made in the assessments, verify technical parameters, define operational locations, configurations, and schedules, and establish common agreement on interference thresholds and performance requirements.

4.0 CRITICAL ASSUMPTIONS

The technical assessments and the associated results are dependent on a number of critical assumptions. These assumptions were made using engineering judgement to help initiate the consideration of sharing issues for the 1755-1850 MHz frequency band. Revision of the assumptions as additional material on technical parameters and operational scenarios becomes available is important to enhance the validity of the work described in this report. The principal assumptions are listed below to aid the reader in evaluating the assessment results. In most cases the critical assumptions are described in greater detail in the appropriate appendix. Changes in any of the assumptions may necessitate revision of certain or all of the assessments.

4.1 IMT-2000 ASSUMPTIONS

- The technical parameters describing IMT-2000 equipment used in this report are a reasonable representation of several candidate IMT-2000 systems that may be deployed in US markets.
- Aggregate IMT-2000 electromagnetic environments for mature networks may be characterized as described in relevant ITU-R documentation.
- IMT-2000 networks will mature over the course of several years with urban areas maturing first.
- On occasion IMT-2000 base station and mobile receivers may operate near minimally acceptable performance levels.

4.2 SATOPS ASSUMPTIONS

- SATOPS minimum antenna elevation angles may fall between 3 and 10 degrees above the horizon.
- SATOPS uplink transmitter powers may range from 100 watts to 10 kW.
- Existing emission spectra and frequency plan of current SATOPS uplinks are as defined in the SATOPS system description.
- SATOPS earth station antennas must support 360° azimuthal coverage.

4.3 TACTICAL RADIO RELAY ASSUMPTIONS

- Transmitter and receiver sites may occur anywhere within selected training ranges.

- National Guard and Reserve units will regularly train with radio relay systems at appropriate sites throughout the country.
- Tactical radio relay systems may occasionally operate near minimally acceptable performance levels.

4.4 ACTS ASSUMPTIONS

- Areas around two test ranges, Cherry Point Marine Corps Air Station (MCAS) in the eastern US and Nellis Air Force Base (AFB) in the western US, may be considered typical locations for determining IMT-2000 aggregate environments to ACTS airborne receivers.
- For determining desired signal levels at airborne receivers, 35 km and 78 km separations from the ground transmitters are typical and near-maximum values, respectively, for the TACTS/ACMI. For the JTCTS, air-to-air transmitter-to-receiver separations of 78 km and 278 km are typical and near-maximum values, respectively.
- An aircraft altitude of 9000 m (29,500 ft) is typical for flight training.
- ACTS ground receiver communications ranges, which affect the usable volume of space for flight training, cannot be reduced by more than ten percent due to interference from IMT-2000 systems.
- ACTS ground station antenna heights of 30 m are typical or near-maximum values.

5.0 SUMMARY OF INITIAL RESULTS AND CONCLUSIONS

The appendixes to this report present the details of the interference assessments for certain DoD equipment and possible IMT-2000 systems operating in the 1755-1850 MHz band. The results of these initial assessments are summarized here. The results presented address only the technical aspects of both full band sharing and the possible band segmentation plans and are based on interference analysis conducted between systems on a one-to-one basis. Interaction among multiple systems was not addressed during this phase. It should be noted that while many instances of undesired interactions are predicted means to mitigate interference have been addressed to some degree. Possible interference mitigation measures are addressed in the next section. The potential risks associated with predicted interactions and possible implementation of mitigation measures are being assessed and will be addressed in the next phase.

5.1 SATELLITE OPERATIONS AND IMT-2000

In full band sharing for SATOPS receivers, interference from IMT-2000 base stations is much more severe than from the mobile stations, but both represent potentially significant interference. The higher the orbit and the lower the elevation angle the more degradation in the link margin, given a constant transmitter power. The negative net margins predicted for the Global Positioning System (GPS) and geostationary orbits indicate that cochannel sharing with IMT-2000 base stations may not be feasible even in the initial stages of IMT-2000 implementation if the predicted levels of interference are realistic. With a fully built out IMT-2000 system, interference at the predicted levels to spacecraft in lower orbits is predicted to be significant. Sharing with mobile stations may be less of a problem. Even so, negative net margins are predicted at the geostationary orbit in 2003 and at the GPS orbit by 2010. Increasing AFSCN transmitter power will minimize the interference on the uplink but will increase interference to IMT–2000 receivers. Note that these predictions are based on traffic loading at the busy hour. Interference levels at other times may be less, depending on the technology employed by the IMT-2000 systems, but they may not be low enough to be negligible. Analysis is ongoing to identify and address factors which may reduce the amount of predicted interference. The operational risks associated with the predicted levels of interference will be addressed in the next phase of this effort.

SATOPS uplink power management and antenna elevation angle restrictions may help to reduce the affected area around the SATOPS uplink transmitter. However, if coordination regions on the order of 10 to 20 km are desired, and IMT-2000 specified interference thresholds are to be met, an order of magnitude decrease in the undesired signal level is required. Additional measures for reducing the uplink power at the IMT-2000 receiver coupled with the power management and antenna restrictions must be implemented to significantly limit the affected area surrounding the uplink site.

Loss of access to 1805-1850 MHz in the near term would render some DoD satellites useless, would preclude emergency TT&C operations with others, and may preclude launch and deployment of others.

Phased sharing may help reduce interactions between SATOPS transmitters and IMT-2000 receivers, but coordination distances may be extremely large. Also, this approach may eventually degrade the performance of SATOPS receivers in the bands where phased sharing is implemented.

5.2 TACTICAL RADIO RELAY AND IMT-2000

Full band sharing of the 1755-1850 MHz frequency range by the IMT-2000 and transportable tactical radio relay may require separation distances on the order of 92 km (main-beam to main-beam) to 55 km (side-lobe to side-lobe) based on conservative interference criteria. Satisfying such separation requirements would be difficult at many locations with tactical radio relay operations. Even if a less conservative interference threshold is used (sensitivity +10 dB for the IMT-2000 and –75 dBm for the AN/GRC-226), the IMT-2000 and tactical radio relay receivers may still require 68 km and 40 km of separation.

Loss of 1805-1850 MHz would present a significant operational risk to tactical radio relay operations as these radios are frequency division duplex and require a minimum frequency separation between transmit and receive frequencies of 50.125 MHz. Loss of this 45 MHz would severely hinder the ability to support large-scale training exercises at any continental US (CONUS) location.

Implementation of phased sharing, with IMT-2000 using a listen-before-transmit capability, may enhance the possibilities of sharing and will be evaluated during the operational assessment.

5.3 AIR COMBAT TRAINING SYSTEMS AND IMT-2000

With full band sharing, the airborne operations of ACTS systems result in large (sometimes in excess of 400 km) separation distances necessary to prevent interactions. Even in the early stages of an IMT-2000 network, interference over large distances may be possible. Required separation distances between ground ACTS equipment and IMT-2000 systems may be well in excess of 100 km depending on site elevations and antenna orientations.

For TACTS/ACMI systems, loss of 1805-1850 MHz would eliminate the ground-to-air frequencies, without which the system as it is currently configured would be inoperable.

Implementation of phased sharing, with IMT-2000 using a listen-before-transmit capability, would enhance the possibilities of sharing, although with ACTS systems the coordination area where such a capability would be needed would be quite large.

5.4 WEAPONS CONTROL LINKS AND IMT-2000

Discussion of interactions between potential IMT-2000 systems and tactical weapons systems is contained in the classified supplement to this report.

6.0 DISCUSSION OF MITIGATION METHODS

Individual system design considerations, environmental site planning, cooperative frequency planning, and other cooperative measures can often mitigate the potential for harmful interference between radio frequency systems. The implementation of interference mitigation measures can greatly enhance opportunities for spectrum sharing. The assessments contained in Appendixes B through E and the classified supplement include suggested means to mitigate possible harmful interference, if undesired interactions were predicted. A complete exploration of mitigation measures was not possible given the uncertainty of some IMT-2000 technical parameters and schedule limitations on this initial assessment. Nevertheless, some mitigation measures have been identified and presented here in a summary form to help initiate consideration of methods to promote spectrum sharing. The order of presentation of the mitigation methods is not prioritized, and other parties may identify many additional methods. A government and industry dialogue on sharing possibilities would be valuable for all concerned organizations, as it is often the case that an interference mitigation method that is viable for one party may be overly restrictive or untenable for the other affected party. The operational risks associated with possible mitigation measures will be addressed in the next phase of this effort.

- In selected areas, implement an IMT-2000 network design that eliminates base station mainbeam illumination of DoD operational areas.
- In selected areas, implement an IMT-2000 network design using minimally acceptable transmitter power levels.
- In selected areas, investigate possible IMT-2000 base station antenna nulling**.**
- Relocate the SATOPS uplink antennas and/or SATOPS transmission off-loading.
- Implement SATOPS antenna elevation angle restrictions.
- Reduce the out-of-beam energy of the SATOPS antennas**.**
- Investigate SATOPS signal blockage, use of RF absorptive material, and antenna redesign.
- Investigate SATOPS power management.
- Identify keep-out zones for IMT-2000 mobile units around designated DoD sites.
- Consider polarization discrimination between SATOPS antennas and IMT-2000 base station antennas.
- Implement cooperative scheduling of SATOPS transmissions with IMT-2000 network operations centers, allowing real-time frequency management.
- Investigate segmenting the 1755-1850 MHz frequency band; however, segmentation of the 1755-1850 MHz band may result in spectrum spillover into adjacent bands.

- Implement cross-polarization between IMT-2000 base stations and tactical radio relay to reduce the level of interference interactions.
- Investigate the possibility of using less conservative interference thresholds by insuring that neither IMT-2000 systems nor DoD systems operate near minimally acceptable signal levels.
- Coordinate antenna orientation of IMT-2000 base stations with the location of the test ranges. The mainbeams of the IMT-2000 antennas should not point in the direction of training range ground stations or of major flight activity, and the IMT-2000 base stations should not be illuminated by the mainbeams of high-gain ACTS ground station antennas.
- Coordinate training range aircraft training schedules with IMT-2000 operations, such that IMT-2000 power levels, frequencies, or antenna orientations could be adjusted to avoid mutual interference.
- Use polarization diversity between IMT-2000 base stations and ACTS equipment, to reduce interference levels for mainbeam-to-mainbeam interactions between IMT-2000 and ACTS equipment.

APPENDIX A – IMT-2000 SYSTEM DESCRIPTION

The greater portion of the IMT-2000 system description presented below has been provided by the FCC. The last part of the system description presents specific technical parameters for selected mobile wireless technologies. These technologies were selected primarily because technical data was more available to describe these systems. The selection of these technologies for use in this assessment does not represent an endorsement or advocacy of those systems. Some of the IMT-2000 parameters used in the assessments were calculated using communications theory and represent notional parameters rather than the characteristics of existing hardware. The parameters contained in this appendix were used in the assessment to help establish the scope of sharing issues. Calculated distances, signal levels, and margins are principally intended to assist in further analyses and to help initiate dialogue between government and industry interest groups.

IMT-2000 and 3G services are the names commonly used to refer to the next-generation mobile wireless telecommunications services. The 3G family of services, and the systems that will provide them, are intended to reflect a high degree of commonality and are to be compatible with each other. These services will support mobile and fixed users employing a wide range of devices including small pocket terminals, handheld telephones, laptop computers, and fixed-receiver equipment. 3G services are envisioned to be ubiquitous throughout the globe, as available in a remote part of a developing country as they are in an urban area in a highly developed country. Seamless roaming is a key attribute. Access to services is expected to be uniform. Furthermore, the user will be able to roam from an urban setting to a suburban one into a rural setting without loss of basic services.[1]

The ITU has been fostering the development of the underlying radio and network standards for what is now defined as IMT-2000 services for over 15 years. The radio transmission technologies (RTTs) providing for standardized 3G air-interfaces adopted in November 1998 were the culmination of many years of arduous effort under the auspices of the ITU's Radiocommunication Sector (ITU-R) Task Group 8/1. These RTTs form the basis for connecting the user's mobile or portable device to the physical infrastructure supporting IMT-2000 services. ITU-R Task Group 8/1 also developed methods that can be used to assess the amount of additional spectrum needed to accommodate the expected future growth in demand for 3G mobile services.[2] The ITU's Telecommunication Standardization (ITU-T) Sector is actively working to develop 3G signaling and communication protocols, network requirements needed to support expected 3G services, and service definitions for

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[1] ITU-R Task Group 8/1 Chairman's Report, ITU-R Radiocommunication Assembly, Istanbul, Turkey, May 2000.

[2] ITU-R Recommendation M. [IMT.SPEC], ITU-R Radiocommunication Assembly, Istanbul, Turkey, May 2000.

IMT-2000 applications. Table A-1 below, derived from ITU-T Draft Recommendation Q.1701,[3] describes selected essential capabilities of IMT-2000 systems.

Consumer demand for services available at any place and the expectation of high quality are key drivers in the effort to establish commonality and compatibility of 3G terrestrial telecommunication systems. It is estimated that by the year 2010 there will be one billion wireless subscribers worldwide on 3G networks.[4] At the present time, the worldwide penetration of wireless service is approximately 7½ percent, and it is expected to exceed 30 percent by the end of the first decade of the new millennium.[5] There are over 1,300 cellular and second-generation terrestrial mobile service networks currently operating worldwide, each with a limited geographic coverage. Hence, it is easy to understand the importance of standardization in system design and service provision for 3G services if uniform services and seamless roaming are to be provided on a regional or global scale.

Table A-1. IMT–2000 Services/Capabilities

Capabilities to support circuit and packet data at high bit rates: - 144 kb/s or higher in high mobility (vehicular) traffic - 384 kb/s or higher for pedestrian traffic - 2 Mb/s or higher for indoor traffic
Interoperability and roaming among IMT–2000 family of systems
Common billing/user profiles: - Sharing of usage/rate information between service providers - Standardized call detail recording - Standardized user profiles
Capability to determine geographic position of mobiles and report it to both the network and the mobile terminal
Support of multimedia services/capabilities: - Fixed and variable rate bit traffic - Bandwidth on demand - Asymmetric data rates in the forward and reverse links - Multimedia mail store and forward - Broadband access up to 2 Mb/s

A.1 SPECTRUM IDENTIFIED FOR IMT-2000

It is generally agreed that IMT-2000, or 3G, systems will require use of spectrum that extends beyond that already encumbered by first- and second-generation mobile systems. A major issue in the global debate regarding 3G system design, standards, and services that must be resolved is the amount of common or “harmonized” spectrum that will be available on a global and regional basis to support 3G systems. For ease in roaming, to help stimulate commonality in services, and economies of scale,

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[3] ITU-T Draft Recommendation Q.1701, Geneva.

[4] United States Talking Points for WRC 2000 on IMT–2000 spectrum requirements.

[5] *Id.*

proponents of 3G services believe it is important to identify as much contiguous harmonized spectrum to support worldwide 3G operations as is practical. This will stimulate the development of global and regional coverage of 3G systems by reducing the cost and complexity for system development, thus providing users with more cost-effective services.

Referring back to the data rates given in the first row in Table A-1, and assuming state-of-the-art data compression capabilities, signal processing gains, and signal processor chip rates, the amount of channel bandwidth needed to provide wireless services at 2 Mb/s could be as much as 15-20 MHz (one-way); at 384 kb/s it could be a high as 5 MHz (one-way). Current second-generation mobile systems easily support 9.6-14.4 kb/s data rates using channel bandwidths of 30-200 kHz, with 64 kb/s being possible when employing sophisticated channelization and coding schemes. The 25 to over 500-fold increase in channel bandwidth needed to provide higher-end data rates dramatically illustrates the reason for the demand for additional spectrum to support 3G wireless services.

A.2 WARC 92

At the 1992 World Administrative Radio Conference (WARC 92), 230 MHz of spectrum at 1885-2025 MHz and 2110-2200 MHz was identified for use by countries wishing to implement 3G systems. Shortly after WARC 92, the FCC conducted auctions for licenses in the paired 1850-1910/1930-1990 MHz band that resulted in personnel communications service (PCS) operators being licensed and authorized to provide advanced mobile wireless communications services throughout the US. The success of the PCS rollout has done much to increase competition in the provision of mobile telecommunications services in the US and at the same time has stimulated the demand for even more advanced wireless services. Recently, countries around the world have started to license 3G systems within paired frequency bands identified at WARC 92 - 1920-1980/2110-2170 MHz.

A.3 WRC-2000

At the WRC-2000 held in Istanbul, additional spectrum to support IMT-2000 services was identified.[6] Three frequency bands, consistent with those proposed by the US to the Conference, were identified for use by administrations wishing to implement IMT-2000 services in addition to those adopted at WARC 92.

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[6] WRC 2000 Final Acts, Istanbul, Turkey, June 2000.

A.4 IMT-2000 SYSTEM CHARACTERISTICS

During preparations for WRC 2000, the US committed to studying the feasibility of using the 1755-1850 MHz and 2500-2690 MHz bands (or parts thereof) for IMT-2000 operations. It was understood that such a study would involve determining the impact of the operation of IMT-2000 systems on the systems already licensed to operate in these bands. The 1755-1850 MHz band is used in the US to support Government services, mostly military space operations, air-to-air training missions, and tactical communications operations. The 1710-1755 MHz portion of the 1700/1800 MHz band identified at WRC 2000 is currently in the process of becoming available for commercial use and it could be made available for IMT–2000 services. The 1850-1885 MHz portion of the same IMT-2000 band is already used to support PCS operations in the US. The 2500-2690 MHz band is used to provide instructional television fixed services (ITFS) and multi-point distribution services (MDS) throughout the US.

Because of the physical processes governing the propagation of radio waves in the frequency range below 3 GHz, these frequencies can be efficiently transmitted and received by small, compact, relatively lightweight user terminals. This feature, coupled with the ability to support high data rates, makes them ideally suited for uses requiring mobility and portability of telecommunications services. Any third-generation service that is targeted at a mobile clientele is most effectively provided by taking advantage of the properties of radio waves operating below 3 GHz. Those 3G applications where the data rates are so high that fixed terminals are needed, or terminals that require antennas so large that they can only be employed in a stationary configuration, are better provided using frequencies above 3 GHz that can more effectively support higher data rate systems. It is the problem of identifying the spectrum bands that can and cannot be used to support 3G services that forms the crux of the effort to assess the degree to which IMT-2000 services can be included in bands already encumbered by services operating at 1755-1850 and 2500-2690 MHz.

In order to determine the impact of operating IMT-2000 systems in bands that are encumbered, it is necessary to assess to what degree the proposed and incumbent systems can co-exist in the same band. Stated in simplistic radio engineering terms, it is necessary to determine whether or not harmful interference is generated into one of the systems (incumbent or proposed) by the operation of the other(s). Furthermore, if it is determined that harmful interference is likely to occur, it is desirable to isolate the conditions under which it occurs and whether or not there exists means to mitigate its effects and costs associated with implementing such mitigation techniques.

The interference assessment mentioned above requires values of the technical characteristics for the systems being studied and the ability to quantify the systems' performance. For the case of the incumbent systems in the bands 1755-1850 MHz and 2500-2690 MHz, it is reasonable to assume that the pertinent parameters required for interference analysis studies are readily available to the individuals tasked with performing the studies. In this report, technical parameters for the incumbent DoD systems are presented in detail in the appendices that document the assessments associated with these systems. This is not the case however for all the parameters that are required to characterize IMT-2000 systems. These systems, many of which are in the planning or development stage, do not have well-defined or universally accepted values associated with every system parameter. Thus it is necessary to assume values for certain of the IMT-2000 system parameters that are to be used in the conduct of the interference studies. When assumptions had to be made concerning values to be used in characterizing IMT-2000 systems, an attempt was made to adopt values that are consistent with values documented in readily available material such as the reports and recommendations of the ITU-R, reports and findings of industry-led working groups addressing IMT-2000 issues, and absent any other readily available information, FCC rules for second-generation (PCS) mobile systems that were used as guides for 3G systems. In addition to values for the technical parameters themselves, it is also necessary to assume certain characteristics of the rollout of proposed IMT-2000 services, such as when they are likely to occur, whether there will be a time-phasing of the rollout, what regions of the globe are likely to support rollout earlier than others, and within a region, whether there will be a geographical preference i.e., urban versus suburban versus rural, for the rollout. These assumptions also were based on as readily available material and information as possible.

Tables A-2 and A-3 provide information on the various IMT–2000 system parameters and rollout characteristics that were used to help initiate the studies being addressed here.

Table A-2. Characteristics of IMT–2000 Mobile (Handset) Stations

Parameter/Characteristic	Value	Source
Transmitter Power	-20dBw 100 milliwatts e.i.r.p. 1 watt e.i.r.p. < 2 watts peak e.i.r.p.	US Doc 6S/16 Rev3[7] NTIA/FCC ITU-R REC M.687-2[8] FCC PCS Rules [9]
Antenna Gain	0 dBi - omni	US Doc 6S/16 Rev3
Antenna Height	< 1 m	Consistency with current 1st and 2nd generation mobile service handsets
Body Loss for handset near head	0 - 2 dB	N/A
Access Techniques	CDMA & TDMA	ITU-R REC M.1455[10]
Receiver Noise Figure	9 dB	US Doc 6S/16 Rev3
Thermal Noise Level	-159 dBw/4 kHz -135 dBw/1 MHz	US Doc 6S/16 Rev3
Operating Bandwidth	CDMA2000 1.25 & 3.75 MHz W-CDMA 1.25 & 5.00 MHz UWC-136 (TDMA) 30 kHz (IS136) 200 kHz (GSM)	ITU-R REC M.1455
Data Rates Supported	144 kb/s in1.25 MHz channel 384 kb/s in 5 MHz channel	ITU-R REC M.1457[11]
Required Carrier-to-Interference (C/I) Ratio	4 dB 8dB	CITEL Executive Briefing Dec. 5, 1999 Ameritech Cellular Presentation[12]
Other Parameters	Frequency stability 3 dB bandwidth out-of-band emissions (OOBE) Receiver sensitivity	ITU-R REC M.1455
N/A = Not Available		

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[7] ITU-R Document US WG 6S/16, Rev 3, August 2000.

[8] ITU-R Recommendation M.687-2, Geneva, 1997.

[9] CFR, Title 47, Part 24.

[10] ITU-R Recommendation M.1455, ITU-R Radiocommunication Assembly, Istanbul, Turkey, May 2000.

[11] ITU-R Recommendation M.1457, ITU-R Radiocommunication Assembly, Istanbul, Turkey, May 2000.

[12] CITEL Executive Briefing Dec. 5, 1999, San Diego, CA, Ameritech Cellular Presentation, Mr. Joe Cruz, presenter.

Table A-3. Characteristics of IMT–2000 Base Stations

Parameter/Characteristic	Value	Source
Transmitter Power	10 W e.i.r.p. < 1640 watts, e.i.r.p.	ITU-R REC 687-2 FCC PCS Rules
Antenna Gain	17 dBi per 120° sector	US Doc 6S/16 Rev3
Tilt of Antenna	2.5° down	US Doc 6S/16 Rev3
Antenna Pattern	Reference antenna for sectoral point-to-multi-point applications	ITU-R REC F. 1336[13] ITU-R Doc 8F/7[14]
Antenna Height	50 m 40 m 300 m	ITU-R 687-2 US Doc 6S/16 Rev3 FCC PCS Rules
Access Techniques	CDMA & TDMA	ITU-R REC M.1455
Receiver Noise Figure	5 dB	US Doc 6S/16 Rev3
Operating Bandwidth	CDMA2000 1.25 & 3.75 MHz W-CDMA 1.25 & 5.00 MHz UWC-136 (TDMA) 30 kHz (IS136) 200 kHz (GSM)	ITU-R REC M.1455
Data Rates Supported	144 kb/s in1.25 MHz channel 384 kb/s in 5 MHz channel	ITU-R REC M.1457
Required Carrier-to-Interference (C/I) Ratio	4 dB 8dB	CITEL Executive Briefing Dec. 5, 1999 Ameritech Cellular Presentation[15]
Thermal Noise Level	-163dBw/4 kHz -139 dBw/1 MHz	US Doc 6S/16 Rev3
Minimum Feeder Loss	1 dB	US Doc 6S/16 Rev3
Other Parameters	Dynamic Range Power Control Steps Frequency Stability 3 dB bandwidth OOBE Receiver sensitivity	ITU-R REC. M.1455

In order to perform the compatibility assessments presented in the appendices, certain specific technical parameters needed additional definition beyond that provided in the tables above. In these cases communications theory and reviews of second generation systems were used to help develop the needed parameters. Tables A-4 through A-7 present the final version of the technical parameters used in the calculations documented in the appendices. It should be noted that the assessments

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[13] ITU-R Recommendation F. 1336, ITU-R Radiocommunication Assembly, Istanbul, Turkey, May 2000.

[14] ITU-R Recommendation F. 1336, ITU-R Radiocommunication Assembly, Istanbul, Turkey, May 2000.

[15] See footnote 12.

considered only one CDMA system simply to limit the scope of the initial assessment. Further analyses and discussions of sharing should consider all of the IMT-2000 technologies equally.

Table A-4. Characteristics of IMT-2000 Mobile Stations

Parameter	CDMA-2000	CDMA-2000	UWC-136 (TDMA)	UWC-136 (TDMA) GPRS/EDGE	W-CDMA
Carrier Spacing	1.25 MHz	3.75 MHz	30 kHz	200 kHz	5 MHz
Transmitter Power	100 mW	100 mW	100 mW	100 mW	100mW
Antenna Gain	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
Body Loss	0 dB	0 dB	0 dB	0 dB	0 dBi
Access Techniques	CDMA	CDMA	TDMA	TDMA	CDMA
Data Rates Supported	144 kbps	384 kbps	30 kbps 44 kbps	384 kbps	384 kbps
Modulation Type	QPSK/BPSK	QPSK/BPSK	π/4-DQPSK 8-PSK	GMSK 8-PSK	QPSK
Emission Bandwidth					
-3 dB	1.1 MHz	3.3 MHz[f]	0.03 MHz	0.18 MHz	3 GPP
-20 dB	1.4 MHz	4.2 MHz	0.03 MHz	0.22 MHz	TS25.101
-60 dB	1.5 MHz	4.5 MHz	0.04 MHz	0.24 MHz	
Receiver Noise Figure	9 dB	9 dB	9 dB	9 dB	9 dB
Receiver Thermal Noise Level	-113. dBm[a] -105 dBm[b]	-109 dBm[a] -100 dBm[b]	-121 dBm[a]	-113 dBm[a]	-109 dBm in 384 kbps
Receiver Bandwidth					
-3 dB	1.10 MHz	3.30 MHz	0.03 MHz	0.18 MHz	N/A
-20 dB	1.6 MHz	4.7 MHz	0.04 MHz	0.25 MHz	N/A
-60 dB	3.7 MHz	11 MHz	0.09 MHz	0.58 MHz	N/A
E_b/N_o for $P_e = 10^{-3}$	6.6 dB	6.6 dB	7.8 dB	8.4 dB	3.1 dB*
Receiver Sensitivity[c]	-107 dBm	-103dBm	-113 dBm	-104 dBm	-106 dBm
Interference Threshold 1[d]	-119 dBm	-115 dBm	-127 dBm	-119 dBm	N/A
Interference Threshold 2[e]	-104 dBm	-100dBm	-111dBm	-103dBm	N/A

[a] in bandwidth equal to data rate
[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] Shaded values were estimated.
* Assumes Eb/No for $P_e = 10^{-6}$ without diversity
N/A = Not Available

Table A-5. Characteristics of IMT-2000 Base Stations

Parameter	CDMA-2000	CDMA-2000	UWC-136 (TDMA)	UWC-136 (TDMA) GPRS/EDGE	W-CDMA
Operating Bandwidth	1.25 MHz	3.75 MHz	30 kHz	200 kHz	5 MHz
Transmitter Power	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
Antenna Height	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
Access Techniques	CDMA	CDMA	TDMA	TDMA	CDMA
Data Rates Supported	144 kbps	384 kbps	30 kbps 44 kbps	384 kbps	384 kbps
Modulation Type	QPSK/BPSK	QPSK/BPSK	π/4-DQPSK 8-PSK	GMSK 8-PSK	QPSK
Emission Bandwidth					
-3 dB	1.1 MHz	3.3 MHz[f]	0.03 MHz	0.18 MHz	3 GPP
-20 dB	1.4 MHz	4.2 MHz	0.03 MHz	0.22 MHz	TS25.104
-60 dB	1.5 MHz	4.5 MHz	0.04 MHz	0.24 MHz	
Receiver Noise Figure	5 dB	5 dB	5 dB	5 dB	5 dB
Receiver Thermal Noise Level	-117dBm[a] -109dBm[b]	-113 dBm[a] -104 dBm[b]	-125 dBm[a]	-117 dBm[a]	-113 dBm in 384 kbps
Receiver Bandwidth					
-3 dB	1.10 MHz	3.3 MHz	0.03 MHz	0.18 MHz	N/A
-20 dB	1.67 MHz	4.7 MHz	0.04 MHz	0.25 MHz	N/A
-60 dB	3.7 MHz	11 MHz	0.09 MHz	0.58 MHz	N/A
E_b/N_o for $P_e = 10^{-3}$	6.6 dB	6.6 dB	7.8 dB	8.4 dB	3.4 dB*
Receiver Sensitivity[c]	-111 dBm	-107 dBm	-117 dBm	-108.Bm	-110 dBm
Interference Threshold 1[d]	-123dBm	-119dBm	-131 dBm	-123 dBm	N/A
Interference Threshold 2[e]	-108 dBm	-104 dBm	-115 dBm	-107dBm	N/A

[a] in bandwidth equal to data rate
[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] Shaded values were estimated.
* Assumes Eb/No for $P_e = 10^{-6}$ without diversity
N/A = Not Available

Table A-6. 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 A-7. Rate of IMT-2000 Network Deployment[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 were taken from ITU-R 687.2 or other reference material as appropriate.

APPENDIX B – POTENTIAL INTERFERENCE TO SATELLITE OPERATIONS

This appendix provides the results of the interim assessment of interference from IMT-2000 to satellite operations (SATOPS) uplinks.

B.1 ASSESSMENT APPROACH

The approach was derived from a previous report prepared by the Air Force Frequency Management Agency.[1] This previous report calculated the estimated interference environment into a spacecraft receiver based upon the power density per square kilometer per Hertz generated by IMT–2000 stations in an urban environment and the population density and urban area sizes visible from the spacecraft.

For this effort, the approach used in this report was to base the calculations of power density upon ITU-R Report M.2023 [2] rather than on the older ITU recommendation used in Reference 1. This change allowed calculations to be performed separately for interference from Mobile Stations and Base Stations. Since Reference 2 indicates that the expected traffic loading will be different in ITU Regions 1, 2, and 3 and will be asymmetrical in some services, it was necessary to consider these additional factors. The aggregation of interference from multiple urban areas was taken directly from Reference 1. A typical satellite link budget from a representative Air Force Satellite Control Network (AFSCN) transmitter to a satellite using a common telemetry, tracking, and commanding (TT&C) transponder (the L3–Com model CXS810–C) was used to compute the link margin in the absence of interference from IMT-2000 transmitters. The aggregate interference level from the IMT-2000 environment was then used to compute the net margin.

B.2 LINK MARGIN CALCULATIONS

Four satellite orbits were chosen for the assessment:

- A 250-kilometer orbit, typical of the Space Transportation System (STS)
- An 833-kilometer orbit, typical of meteorological satellites such as Defense Meteorological Satellite Program (DMSP)

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[1] Wayne Wamback, *The Potential for Interference Between IMT-2000 Systems and U.S. DoD Systems Operating in the Frequency Band 1755 – 1850 MHz,* Washington, DC: Air Force Frequency Management Agency, 28 February 2000.

[2] *Spectrum Requirements for International Mobile Telecommunications–2000 (IMT–2000),* Report ITU–R M.2023, Geneva, Switzerland, 2000.

- A 22,200-kilometer orbit, typical of the Global Positioning System (GPS)
- A 35,784-kilometer orbit, typical of geostationary satellites

For the two lowest orbits, three hypothetical AFSCN transmitter powers, 250 W, 2000 W, and 7000 W, were used in the assessment. For the other two orbits only the 2000 W and 7000 W powers were used. These power levels may not be the actual powers normally used in AFSCN operations, but are representative of AFSCN capabilities.

Antenna characteristics were taken from an AFSCN Specification.[3] For this assessment, a 46-foot antenna with a gain of 41 dBi was selected for the AFSCN station. A spacecraft antenna with a –5 dBi gain was assumed as typical. Propagation losses took into account free-space path loss, cloud loss, rain loss, atmospheric loss, and polarization loss based on the slant-range to the spacecraft. Three AFSCN station elevation angles were used to determine the losses through the earth's atmosphere.

The spacecraft effective receiver system temperature was 798 Kelvin, and the threshold service powers were –113 dBm for the Command service and –120 dBm for the Carrier and Ranging services.

Link margin calculations were based on the traffic loading characteristics of ITU Region 2 (the Americas). The aggregation of interference taken from Reference 1 did not distinguish between ITU regions. Since the power densities per square kilometer per Hertz from the other regions differed by less than 1 dB for the Base Stations and by approximately 3 dB for the Mobile Stations, it is reasonable to assume that the Region 2 values are indicative of the interference environment worldwide.

An example of the link budget and the net margin calculations is shown in Table B-1. The results of the link margin calculations are shown in Tables B-2 through B-9. Separate tables are shown for interference from mobile stations and base stations for each of the years 2003, 2006, and 2010 as well as for a future full buildout of the IMT-2000 system.

It was assumed that the worst-case IMT–2000 power density that a spacecraft receiver is exposed to is independent of orbital altitude. The implication is that the increase in received power due to the increase in quantities of IMT-2000 transmitters visible to the spacecraft as the altitude increases is offset by the propagation path loss increase with altitude. The limited data included in Reference 1 suggest that the error associated with this assumption may be less than 4 dB. Verification of this assumption

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[3] *Standardized Interface Specification between Air Force Satellite Control Network Common User Element and Comm/Range Segment and Space Vehicle*, AFSCN SIS-000502A, El Segundo, CA, Space and Missiles System Center, 22 October 1997.

would have required a more detailed simulation than was possible in the time available for this interim analysis.

B.3 CONCLUSIONS

Interference from IMT–2000 base stations is much more severe than from the mobile stations, but both represent potentially significant interference to SATOPS. The higher the orbit and the lower the elevation angle the more degradation in the link margin, given a constant transmitter power. The negative net margins predicted for the Global Positioning System (GPS) and geostationary orbits indicate that cochannel sharing with IMT-2000 base stations may not be feasible even in the initial stages of IMT-2000 implementation if the predicted levels of interference are realistic. With a fully built out IMT-2000 system, interference at the predicted levels to spacecraft in lower orbits is expected to be significant. Sharing with mobile stations will be less of a problem. Even so, negative net margins are predicted at the geostationary orbit in 2003 and at the GPS orbit by 2010. Increasing AFSCN transmitter power will minimize the interference on the uplink, but will increase interference to IMT-2000 receivers. Note that these predictions are based on traffic loading at the busy hour. Interference levels at other times may be less, depending on the technology employed by the IMT–2000 systems, but may not be low enough to be negligible.

This interim assessment represents a worst-case situation. There are several factors, not considered in this assessment due to time constraints, which may reduce the amount of interference predicted. These factors include the vertical radiation patterns of the IMT–2000 base station antennas, power management in the IMT–2000 systems, variations among IMT–2000 technologies, and the approximations inherent in the algorithms used to predict the aggregate interference. Further analysis is ongoing and the results will be incorporated in the final assessment.

The operational impact of the predicted levels of interference needs to be addressed. Implementation strategies also need to be investigated to determine if it is feasible to implement the IMT-2000 buildout in a way which could mitigate interference to SATOPS.

Table B-1. Typical Link Budget

Typical Link Budget					
Frequency	1800.0	MHz			
TX Power	7000.0	Watts			
TX Power	68.5	dBm			
TX EIRP	107.0	dBm			
TX Ant Diameter	46.0	Ft	From SIS-0502		
TX Ant Beamwidth	0.6	Deg			
TX Ant Gain	41.0	dBi	From SIS-0502		
Orbit Height	20200.0	Km			
Elevation Angle	10.0	Deg			
Mean Earth Radius	6378.1	Km			
Slant Range	24717.7	Km			
Space Loss	185.4	dB			
Cloud Loss	0.0	dB			
Rain Loss	1.6	dB			
Atmospheric Loss	0.2	dB			
Polarization Loss	0.5	dB			
Scintillation Loss	0.0	dB			
Rx Antenna Gain	-5.0	dB			
Rx Antenna Temp	300.0	K			
Rx Diplexer Loss	0.3	dB			
Rx Coupler Loss	1.0	dB			
Rx Cable Loss	2.0	dB			
Rx Cable Temp	169.6	K			
Total Rx Line Loss	3.3	dB			
Receiver NF	5.0	dB			
Receiver Temp	627.1	K			
Eff Rx Ant Temp	171.0	K			
Rx System Temp	798.1	K			
Rx System Temp	29.0	K			
Rx System Gain	-5.0	dB			
Rx G/T	-34.0	dB/K			
Rx Isotropic Carrier Pwr	-86.5	dBm			
	CMD	Carrier	Ranging		
Mod Index	0.6		0.3		
Mod Loss	-7.8	-0.6	-10.8	dB	
Min Received Service Power	-94.3	-87.1	-97.3	dBm	
Threshold Service Power for a CXS810-C	-113.0	-120.0	-120.0	dBm	From L3-Com Spec
Data Rate	2048.0			Kb/s	From SIS-0502
Link Margin	18.7	32.9	22.7	dB	
System Noise	-198.3	-198.3	-198.3	dBW/Hz	
IMT-2000 Noise	-161.4	-161.4	-161.4	dBW/Hz	
Net Margin	-18.2	-4.0	-14.2	dB	

Table B-2. Interference from IMT-2000 Mobile Stations in 2003

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)			Net Margin With Interference (dB)		
				Command	Carrier	Ranging	Command	Carrier	Ranging
STS	250 km	250 W	3 deg	28.2	42.4	32.2	18.2	32.4	22.2
			5 deg	29.4	43.6	33.4	19.4	33.6	23.4
			10 deg	32.0	46.2	36.0	22.0	36.2	26.0
		2000 W	3 deg	37.2	51.4	41.2	27.2	41.4	31.2
			5 deg	38.4	52.6	42.4	28.4	42.6	32.5
			10 deg	41.0	55.2	45.0	31.0	45.2	35.0
		7000 W	3 deg	42.6	56.8	46.7	32.6	46.8	36.7
			5 deg	43.9	58.1	47.9	33.9	48.1	37.9
			10 deg	46.5	60.7	50.5	36.5	50.7	40.5
DMSP	833 km	250 W	3 deg	22.0	36.2	26.0	12.0	26.2	16.0
			5 deg	22.8	37.0	26.8	12.8	27.0	16.8
			10 deg	24.3	38.5	28.4	14.3	28.5	18.4
		2000 W	3 deg	31.0	45.2	35.1	21.0	35.2	25.1
			5 deg	31.8	46.0	35.8	21.8	36.0	25.8
			10 deg	33.4	47.6	37.4	23.4	37.6	27.4
		7000 W	3 deg	36.5	50.7	40.5	26.5	40.7	30.5
			5 deg	37.2	51.4	41.3	27.2	41.4	31.3
			10 deg	38.8	53.0	42.8	28.8	43.0	32.8
GPS	20,200 km	2000 W	3 deg	12.6	26.8	16.6	2.6	16.8	6.6
			5 deg	12.9	27.1	16.9	2.9	17.1	6.9
			10 deg	13.2	27.4	17.3	3.2	17.4	7.3
		7000 W	3 deg	18.0	32.2	22.1	8.0	22.2	12.1
			5 deg	18.3	32.5	22.3	8.3	22.5	12.3
			10 deg	18.7	32.9	22.7	8.7	22.9	12.7
GEO	35,784 km	2000 W	3 deg	8.4	22.6	12.4	-1.6	12.6	2.4
			5 deg	8.6	22.8	12.7	-1.4	12.8	2.7
			10 deg	8.9	23.1	12.9	-1.1	13.1	2.9
		7000 W	3 deg	13.8	28.0	17.8	3.8	18.0	7.8
			5 deg	14.1	28.3	18.1	4.1	18.3	8.1
			10 deg	14.4	28.6	18.4	4.4	18.6	8.4

Table B-3. Interference from IMT-2000 Mobile Stations in 2006

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)			Net Margin With Interference (dB)		
				Command	Carrier	Ranging	Command	Carrier	Ranging
STS	250 km	250 W	3 deg	28.2	42.4	32.2	11.2	25.4	15.2
			5 deg	29.4	43.6	33.4	12.4	26.6	16.4
			10 deg	32.0	46.2	36.0	15.0	29.2	19.0
		2000 W	3 deg	37.2	51.4	41.2	20.2	34.4	24.2
			5 deg	38.4	52.6	42.4	21.4	35.6	25.5
			10 deg	41.0	55.2	45.0	24.0	38.2	28.1
		7000 W	3 deg	42.6	56.8	46.7	25.7	39.9	29.7
			5 deg	43.9	58.1	47.9	26.9	41.1	30.9
			10 deg	46.5	60.7	50.5	29.5	43.7	33.5
DMSP	833 km	250 W	3 deg	22.0	36.2	26.0	5.0	19.2	9.0
			5 deg	22.8	37.0	26.8	5.8	20.0	9.8
			10 deg	24.3	38.5	28.4	7.3	21.5	11.4
		2000 W	3 deg	31.0	45.2	35.1	14.0	28.2	18.1
			5 deg	31.8	46.0	35.8	14.8	29.0	18.8
			10 deg	33.4	47.6	37.4	16.4	30.6	20.4
		7000 W	3 deg	36.5	50.7	40.5	19.5	33.7	23.5
			5 deg	37.2	51.4	41.3	20.3	34.5	24.3
			10 deg	38.8	53.0	42.8	21.8	36.0	25.8
GPS	20,200 km	2000 W	3 deg	12.6	26.8	16.6	-4.4	9.8	-0.4
			5 deg	12.9	27.1	16.9	-4.1	10.1	-0.1
			10 deg	13.2	27.4	17.3	-3.8	10.4	0.3
		7000 W	3 deg	18.0	32.2	22.1	1.0	15.2	5.1
			5 deg	18.3	32.5	22.3	1.3	15.5	5.3
			10 deg	18.7	32.9	22.7	1.7	15.9	5.7
GEO	35,784 km	2000 W	3 deg	8.4	22.6	12.4	-8.6	5.6	-4.6
			5 deg	8.6	22.8	12.7	-8.4	5.8	-4.3
			10 deg	8.9	23.1	12.9	-8.1	6.1	-4.0
		7000 W	3 deg	13.8	28.0	17.8	-3.2	11.0	0.9
			5 deg	14.1	28.3	18.1	-2.9	11.3	1.1
			10 deg	14.4	28.6	18.4	-2.6	11.6	1.4

Table B-4. Interference from IMT-2000 Mobile Stations in 2010

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)			Net Margin With Interference (dB)		
				Command	Carrier	Ranging	Command	Carrier	Ranging
STS	250 km	250 W	3 deg	28.2	42.4	32.2	8.7	22.9	12.7
			5 deg	29.4	43.6	33.4	9.9	24.1	13.9
			10 deg	32.0	46.2	36.0	12.5	26.7	16.5
		2000 W	3 deg	37.2	51.4	41.2	17.7	31.9	21.7
			5 deg	38.4	52.6	42.4	18.9	33.1	23.0
			10 deg	41.0	55.2	45.0	21.5	35.7	25.6
		7000 W	3 deg	42.6	56.8	46.7	23.2	37.4	27.2
			5 deg	43.9	58.1	47.9	24.4	38.6	28.4
			10 deg	46.5	60.7	50.5	27.0	41.2	31.0
DMSP	833 km	250 W	3 deg	22.0	36.2	26.0	2.5	16.7	6.5
			5 deg	22.8	37.0	26.8	3.2	17.4	7.3
			10 deg	24.3	38.5	28.4	4.8	19.0	8.8
		2000 W	3 deg	31.0	45.2	35.1	11.5	25.7	15.6
			5 deg	31.8	46.0	35.8	12.3	26.5	16.3
			10 deg	33.4	47.6	37.4	13.9	28.1	17.9
		7000 W	3 deg	36.5	50.7	40.5	17.0	31.2	21.0
			5 deg	37.2	51.4	41.3	17.8	32.0	21.8
			10 deg	38.8	53.0	42.8	19.3	33.5	23.3
GPS	20,200 km	2000 W	3 deg	12.6	26.8	16.6	-6.9	7.3	-2.9
			5 deg	12.9	27.1	16.9	-6.6	7.6	-2.6
			10 deg	13.2	27.4	17.3	-6.3	7.9	-2.2
		7000 W	3 deg	18.0	32.2	22.1	-1.5	12.7	2.6
			5 deg	18.3	32.5	22.3	-1.2	13.0	2.8
			10 deg	18.7	32.9	22.7	-0.8	13.4	3.2
GEO	35,784 km	2000 W	3 deg	8.4	22.6	12.4	-11.2	3.0	-7.1
			5 deg	8.6	22.8	12.7	-10.9	3.3	-6.9
			10 deg	8.9	23.1	12.9	-10.6	3.6	-6.6
		7000 W	3 deg	13.8	28.0	17.8	-5.7	8.5	-1.7
			5 deg	14.1	28.3	18.1	-5.5	8.7	-1.4
			10 deg	14.4	28.6	18.4	-5.2	9.0	-1.2

Table B-5. Interference from IMT-2000 Mobile Stations at Full Buildout

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)			Net Margin With Interference (dB)		
				Command	Carrier	Ranging	Command	Carrier	Ranging
STS	250 km	250 W	3 deg	28.2	42.4	32.2	8.2	22.4	12.2
			5 deg	29.4	43.6	33.4	9.4	23.6	13.5
			10 deg	32.0	46.2	36.0	12.0	26.2	16.1
		2000 W	3 deg	37.2	51.4	41.2	17.2	31.4	21.3
			5 deg	38.4	52.6	42.4	18.5	32.7	22.5
			10 deg	41.0	55.2	45.0	21.1	35.3	25.1
		7000 W	3 deg	42.6	56.8	46.7	22.7	36.9	26.7
			5 deg	43.9	58.1	47.9	23.9	38.1	27.9
			10 deg	46.5	60.7	50.5	26.5	40.7	30.5
DMSP	833 km	250 W	3 deg	22.0	36.2	26.0	2.0	16.2	6.0
			5 deg	22.8	37.0	26.8	2.8	17.0	6.8
			10 deg	24.3	38.5	28.4	4.3	18.5	8.4
		2000 W	3 deg	31.0	45.2	35.1	11.1	25.3	15.1
			5 deg	31.8	46.0	35.8	11.8	26.0	15.9
			10 deg	33.4	47.6	37.4	13.4	27.6	17.4
		7000 W	3 deg	36.5	50.7	40.5	16.5	30.7	20.5
			5 deg	37.2	51.4	41.3	17.3	31.5	21.3
			10 deg	38.8	53.0	42.8	18.8	33.0	22.9
GPS	20,200 km	2000 W	3 deg	12.6	26.8	16.6	-7.4	6.8	-3.3
			5 deg	12.9	27.1	16.9	-7.1	7.1	-3.1
			10 deg	13.2	27.4	17.3	-6.7	7.5	-2.7
		7000 W	3 deg	18.0	32.2	22.1	-1.9	12.3	2.1
			5 deg	18.3	32.5	22.3	-1.6	12.6	2.4
			10 deg	18.7	32.9	22.7	-1.3	12.9	2.7
GEO	35,784 km	2000 W	3 deg	8.4	22.6	12.4	-11.6	2.6	-7.6
			5 deg	8.6	22.8	12.7	-11.4	2.8	-7.3
			10 deg	8.9	23.1	12.9	-11.1	3.1	-7.1
		7000 W	3 deg	13.8	28.0	17.8	-6.2	8.0	-2.2
			5 deg	14.1	28.3	18.1	-5.9	8.3	-1.9
			10 deg	14.4	28.6	18.4	-5.6	8.6	-1.6

Table B-6. Interference from IMT-2000 Base Stations in 2003

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)			Net Margin With Interference (dB)		
				Command	Carrier	Ranging	Command	Carrier	Ranging
STS	250 km	250 W	3 deg	28.2	42.4	32.2	1.3	15.5	5.3
			5 deg	29.4	43.6	33.4	2.5	16.7	6.6
			10 deg	32.0	46.2	36.0	5.1	19.3	9.2
		2000 W	3 deg	37.2	51.4	41.2	10.3	24.5	14.4
			5 deg	38.4	52.6	42.4	11.6	25.8	15.6
			10 deg	41.0	55.2	45.0	14.2	28.4	18.2
		7000 W	3 deg	42.6	56.8	46.7	15.8	30.0	19.8
			5 deg	43.9	58.1	47.9	17.0	31.2	21.0
			10 deg	46.5	60.7	50.5	19.6	33.8	23.6
DMSP	833 km	250 W	3 deg	22.0	36.2	26.0	-4.9	9.3	-0.8
			5 deg	22.8	37.0	26.8	-4.1	10.1	-0.1
			10 deg	24.3	38.5	28.4	-2.5	11.7	1.5
		2000 W	3 deg	31.0	45.2	35.1	4.2	18.4	8.2
			5 deg	31.8	46.0	35.8	4.9	19.1	9.0
			10 deg	33.4	47.6	37.4	6.5	20.7	10.5
		7000 W	3 deg	36.5	50.7	40.5	9.6	23.8	13.6
			5 deg	37.2	51.4	41.3	10.4	24.6	14.4
			10 deg	38.8	53.0	42.8	11.9	26.1	16.0
GPS	20,200 km	2000 W	3 deg	12.6	26.8	16.6	-14.3	-0.1	-10.2
			5 deg	12.9	27.1	16.9	-14.0	0.2	-10.0
			10 deg	13.2	27.4	17.3	-13.6	0.6	-9.6
		7000 W	3 deg	18.0	32.2	22.1	-8.8	5.4	-4.8
			5 deg	18.3	32.5	22.3	-8.5	5.7	-4.5
			10 deg	18.7	32.9	22.7	-8.2	6.0	-4.2
GEO	35,784 km	2000 W	3 deg	8.4	22.6	12.4	-18.5	-4.3	-14.5
			5 deg	8.6	22.8	12.7	-18.2	-4.0	-14.2
			10 deg	8.9	23.1	12.9	-17.9	-3.7	-13.9
		7000 W	3 deg	13.8	28.0	17.8	-13.0	1.2	-9.0
			5 deg	14.1	28.3	18.1	-12.8	1.4	-8.8
			10 deg	14.4	28.6	18.4	-12.5	1.7	-8.5

Table B-7. Interference from IMT-2000 Base Stations in 2006

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)			Net Margin With Interference (dB)		
				Command	Carrier	Ranging	Command	Carrier	Ranging
STS	250 km	250 W	3 deg	28.2	42.4	32.2	-5.7	8.5	-1.7
			5 deg	29.4	43.6	33.4	-4.4	9.8	-0.4
			10 deg	32.0	46.2	36.0	-1.9	12.3	2.2
		2000 W	3 deg	37.2	51.4	41.2	3.4	17.6	7.4
			5 deg	38.4	52.6	42.4	4.6	18.8	8.6
			10 deg	41.0	55.2	45.0	7.2	21.4	11.2
		7000 W	3 deg	42.6	56.8	46.7	8.8	23.0	12.8
			5 deg	43.9	58.1	47.9	10.0	24.2	14.0
			10 deg	46.5	60.7	50.5	12.6	26.8	16.6
DMSP	833 km	250 W	3 deg	22.0	36.2	26.0	-11.8	2.4	-7.8
			5 deg	22.8	37.0	26.8	-11.1	3.1	-7.1
			10 deg	24.3	38.5	28.4	-9.5	4.7	-5.5
		2000 W	3 deg	31.0	45.2	35.1	-2.8	11.4	1.2
			5 deg	31.8	46.0	35.8	-2.0	12.2	2.0
			10 deg	33.4	47.6	37.4	-0.5	13.7	3.5
		7000 W	3 deg	36.5	50.7	40.5	2.6	16.8	6.6
			5 deg	37.2	51.4	41.3	3.4	17.6	7.4
			10 deg	38.8	53.0	42.8	5.0	19.2	9.0
GPS	20,200 km	2000 W	3 deg	12.6	26.8	16.6	-21.3	-7.1	-17.2
			5 deg	12.9	27.1	16.9	-21.0	-6.8	-17.0
			10 deg	13.2	27.4	17.3	-20.6	-6.4	-16.6
		7000 W	3 deg	18.0	32.2	22.1	-15.8	-1.6	-11.8
			5 deg	18.3	32.5	22.3	-15.5	-1.3	-11.5
			10 deg	18.7	32.9	22.7	-15.2	-1.0	-11.2
GEO	35,784 km	2000 W	3 deg	8.4	22.6	12.4	-25.5	-11.3	-21.4
			5 deg	8.6	22.8	12.7	-25.2	-11.0	-21.2
			10 deg	8.9	23.1	12.9	-24.9	-10.7	-20.9
		7000 W	3 deg	13.8	28.0	17.8	-20.0	-5.8	-16.0
			5 deg	14.1	28.3	18.1	-19.8	-5.6	-15.8
			10 deg	14.4	28.6	18.4	-19.5	-5.3	-15.5

Table B-8. Interference from IMT-2000 Base Stations in 2010

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)			Net Margin With Interference (dB)		
				Command	Carrier	Ranging	Command	Carrier	Ranging
STS	250 km	250 W	3 deg	28.2	42.4	32.2	-8.2	6.0	-4.2
			5 deg	29.4	43.6	33.4	-7.0	7.2	-3.0
			10 deg	32.0	46.2	36.0	-4.4	9.8	-0.4
		2000 W	3 deg	37.2	51.4	41.2	0.8	15.0	4.8
			5 deg	38.4	52.6	42.4	2.0	16.2	6.1
			10 deg	41.0	55.2	45.0	4.6	18.8	8.6
		7000 W	3 deg	42.6	56.8	46.7	6.2	20.4	10.3
			5 deg	43.9	58.1	47.9	7.5	21.7	11.5
			10 deg	46.5	60.7	50.5	10.1	24.3	14.1
DMSP	833 km	250 W	3 deg	22.0	36.2	26.0	-14.4	-0.2	-10.4
			5 deg	22.8	37.0	26.8	-13.6	0.6	-9.6
			10 deg	24.3	38.5	28.4	-12.1	2.1	-8.0
		2000 W	3 deg	31.0	45.2	35.1	-5.4	8.8	-1.3
			5 deg	31.8	46.0	35.8	-4.6	9.6	-0.6
			10 deg	33.4	47.6	37.4	-3.0	11.2	1.0
		7000 W	3 deg	36.5	50.7	40.5	0.1	14.3	4.1
			5 deg	37.2	51.4	41.3	0.8	15.0	4.9
			10 deg	38.8	53.0	42.8	2.4	16.6	6.4
GPS	20,200 km	2000 W	3 deg	12.6	26.8	16.6	-23.8	-9.6	-19.8
			5 deg	12.9	27.1	16.9	-23.5	-9.3	-19.5
			10 deg	13.2	27.4	17.3	-23.2	-9.0	-19.1
		7000 W	3 deg	18.0	32.2	22.1	-18.4	-4.2	-14.3
			5 deg	18.3	32.5	22.3	-18.1	-3.9	-14.1
			10 deg	18.7	32.9	22.7	-17.7	-3.5	-13.7
GEO	35,784 km	2000 W	3 deg	8.4	22.6	12.4	-28.0	-13.8	-24.0
			5 deg	8.6	22.8	12.7	-27.8	-13.6	-23.7
			10 deg	8.9	23.1	12.9	-27.5	-13.3	-23.5
		7000 W	3 deg	13.8	28.0	17.8	-22.6	-8.4	-18.6
			5 deg	14.1	28.3	18.1	-22.3	-8.1	-18.3
			10 deg	14.4	28.6	18.4	-22.0	-7.8	-18.0

Table B-9. Interference from IMT-2000 Base Stations at Full Buildout

Typical Spacecraft	Orbit Altitude	AFSCN TX Power	Elevation Angle	Link Margin Without Interference (dB)			Net Margin With Interference (dB)		
				Command	Carrier	Ranging	Command	Carrier	Ranging
STS	250 km	250 W	3 deg	28.2	42.4	32.2	-8.7	5.5	-4.7
			5 deg	29.4	43.6	33.4	-7.5	6.7	-3.4
			10 deg	32.0	46.2	36.0	-4.9	9.3	-0.8
		2000 W	3 deg	37.2	51.4	41.2	0.3	14.5	4.4
			5 deg	38.4	52.6	42.4	1.6	15.8	5.6
			10 deg	41.0	55.2	45.0	4.2	18.4	8.2
		7000 W	3 deg	42.6	56.8	46.7	5.8	20.0	9.8
			5 deg	43.9	58.1	47.9	7.0	21.2	11.0
			10 deg	46.5	60.7	50.5	9.6	23.8	13.6
DMSP	833 km	250 W	3 deg	22.0	36.2	26.0	-14.9	-0.7	-10.8
			5 deg	22.8	37.0	26.8	-14.1	0.1	-10.1
			10 deg	24.3	38.5	28.4	-12.5	1.7	-8.5
		2000 W	3 deg	31.0	45.2	35.1	-5.8	8.4	-1.8
			5 deg	31.8	46.0	35.8	-5.1	9.1	-1.0
			10 deg	33.4	47.6	37.4	-3.5	10.7	0.5
		7000 W	3 deg	36.5	50.7	40.5	-0.4	13.8	3.6
			5 deg	37.2	51.4	41.3	0.4	14.6	4.4
			10 deg	38.8	53.0	42.8	1.9	16.1	6.0
GPS	20,200 km	2000 W	3 deg	12.6	26.8	16.6	-24.3	-10.1	-20.2
			5 deg	12.9	27.1	16.9	-24.0	-9.8	-20.0
			10 deg	13.2	27.4	17.3	-23.6	-9.4	-19.6
		7000 W	3 deg	18.0	32.2	22.1	-18.8	-4.6	-14.8
			5 deg	18.3	32.5	22.3	-18.5	-4.3	-14.5
			10 deg	18.7	32.9	22.7	-18.2	-4.0	-14.2
GEO	35,784 km	2000 W	3 deg	8.4	22.6	12.4	-28.5	-14.3	-24.5
			5 deg	8.6	22.8	12.7	-28.2	-14.0	-24.2
			10 deg	8.9	23.1	12.9	-27.9	-13.7	-23.9
		7000 W	3 deg	13.8	28.0	17.8	-23.0	-8.8	-19.0
			5 deg	14.1	28.3	18.1	-22.8	-8.6	-18.8
			10 deg	14.4	28.6	18.4	-22.5	-8.3	-18.5

APPENDIX C – POTENTIAL INTERFERENCE FROM SATELLITE OPERATIONS UPLINK TO IMT-2000 RECEIVERS

The US Department of Defense conducts satellite operations (SATOPS) functions in the 1755-1850 MHz and 2200-2290 MHz bands to maintain control and receive health and status data on over 120 satellites flying in both geostationary and non-geostationary orbits. The consideration of IMT-2000 operations within S-band raises the potential for interference both to and from SATOPS. This appendix addresses the potential for interference from the SATOPS uplink to IMT-2000 receivers.

C.1 ASSESSMENT APPROACH

In order to assess the potential for interference to a geographically dispersed network of IMT-2000 fixed and mobile receivers, an automated model was used to generate received signal overlays as a function of transmitter and receiver parameters and terrain-dependent path loss. The results are displayed as a raster or grid of color-coded signal levels overlayed on a map. The basis for the terrain-dependent path loss calculations within the model is the Terrain-Dependent Path Loss Model (TIREM).

In recognition of the significant variations in SATOPS transmitter uplink and IMT-2000 receiver configurations, a parametric analysis was performed. For SATOPS uplink functions, minimum antenna elevation angles of 3, 5, and 10 degrees were selected. Additional higher minimum elevation angles were not considered because the minimal benefit in sidelobe reduction was offset by the significant impact to operations. Based on current antenna configurations, significant sidelobe reduction is not realized until well outside of the mainbeam. These angles would be prohibitively large for typical SATOPs functions, particularly for those conducted on satellites flying in non-geostationary orbits.

For the IMT-2000 receivers, separate overlays were generated for the base stations and mobiles/portables in recognition of the differences in receiver antenna height, antenna gain, and interference threshold.

C.2 SATOPS SYSTEMS DESCRIPTION

The DoD SATOPS uplink functions, which include the transmission of commanding and ranging signals, are performed in the 1755-1850 MHz band. Downlink telemetry data is passed via the 2200-2290 MHz band. The Air Force Satellite Control Network (AFSCN) is a worldwide network of US Air Force ground stations and control centers which provide telemetry, tracking, and commanding (TT&C) services to DoD satellites. The AFSCN consists of two control nodes, Schriever AFB, CO, and Onizuka Air station (OAS) at Sunnyvale, CA, plus eight Automated Remote Tracking Stations (ARTS) dispersed both within and outside the US. Figure C-1 depicts the locations of the AFSCN ground stations. Table C-1 lists the terminal sizes and locations for the US sites considered in this assessment. The Navy also operates Space Ground Link Subsystem (SGLS) earth stations at the following locations: Prospect Harbor, ME, Laguna Peak, CA, Finegayan, Guam, as well as Blossom Point, MD, and Quantico, VA.

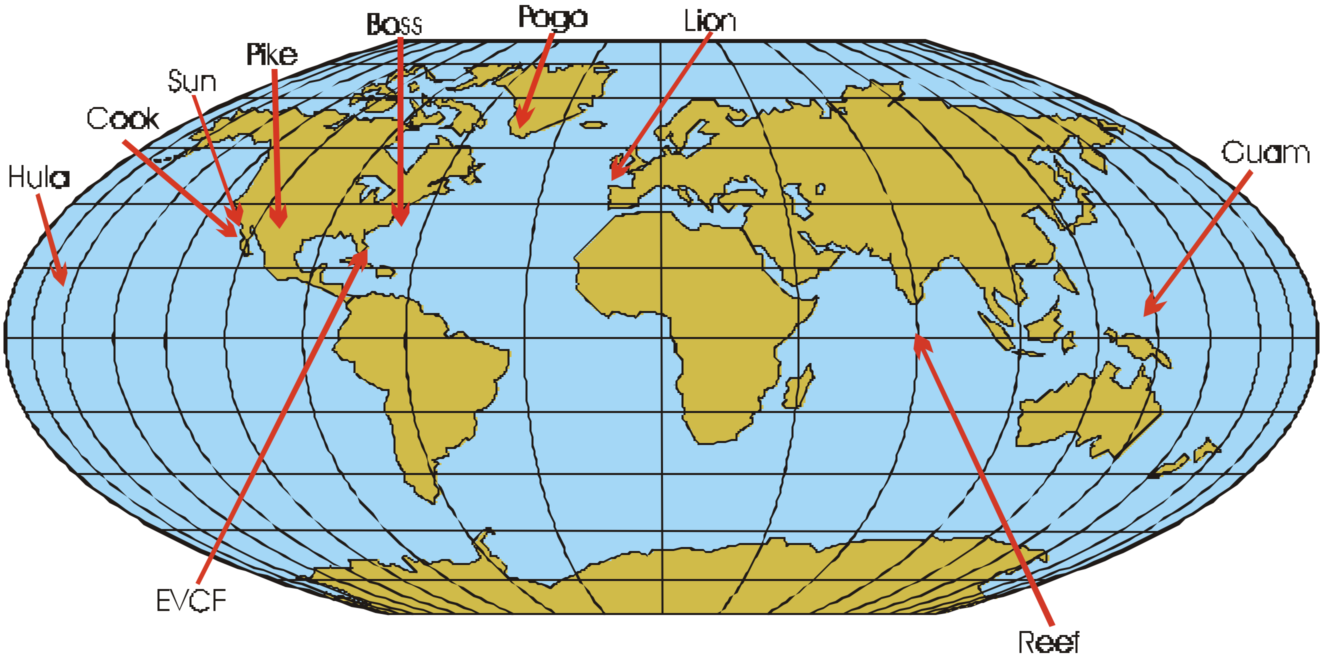


Figure C-1. Locations of the AFSCN Ground Stations

Table C-1. SATOPS Uplink Sites Included in this Assessment

Terminal Name	Abbreviation	Alt Nam	Location	Latitude/ Longitude	Number of Terminals	Terminal Size (feet)
Colorado Tracking Station	CTS	Pike	Colorado Springs, CO	38 48 21 N 104 31 43 W	1	33
New Hampshire Tracking Station	NHS	Boss	Manchester, NH	42 56 52 N 071 37 37 W	3	60 46 33
Onizuka Air Station	OAS	Sun	Sunnyvale, CA	37 24 25 N 122 0134 W	1	51
Eastern Vehicle Check-out Facility	EVCF	EVCF	Cape Canaveral, FL	28 27 29 N 080 34 32 W	1	23

Table C-2 lists the 20 center frequencies for the standard AFSCN uplink frequency plan. It should be noted that historically, most SATOPS uplinks conformed to the 20-channel plan. However, in an effort to become more spectrally efficient, plans are in effect to deploy hardware with the capability to tune to channels in-between those reflected in the standard plan.

Figure C-2 is a computer generated emission signature of the SATOPS uplink spectrum showing the combined baseband command, data, and ranging signal as a function of the high-power amplifier (HPA) and filtering. The figure clearly shows the benefit of baseband filtering, a technique that is currently not implemented at the AFSCN sites. In the absence of such filtering, the undesirable spectral products and limited roll-off of the out-of-band components is apparent. As will be discussed, the wideband unfiltered structure of the current SGLS waveform transmitted using the current class C amplifiers limits the benefits obtained from off-tuning SATOPS and IMT-2000 systems.

Table C-2. AFSCN SATOPS Uplink Frequency Plan

S-band Channel	Uplink Frequency Transmission (MHz)	S-band Channel	Uplink Frequency Transmission (MHz)
1	1763.720703	11	1803.759766
2	1767.724609	12	1807.763672
3	1771.728515	13	1811.767578
4	1775.732422	14	1815.771484
5	1779.736328	15	1819.775391
6	1783.740234	16	1823.779297
7	1787.744141	17	1827.783203
8	1791.748047	18	1831.787109
9	1795.751953	19	1835.791016
10	1799.755859	20	1839.794922

C.3 MODEL INPUTS

Table C-3 lists the IMT-2000 data used to generate the received signal overlays. This data has been coordinated with the FCC and is consistent with IMT-2000 system specifications used to assess the other types of DoD systems in the band. Receiver interference thresholds are grouped into 10-dB bins from the most sensitive threshold provided (-121 dBm) up to greater than -71 dBm. This range of thresholds more than encompasses the region of acceptable interference values.

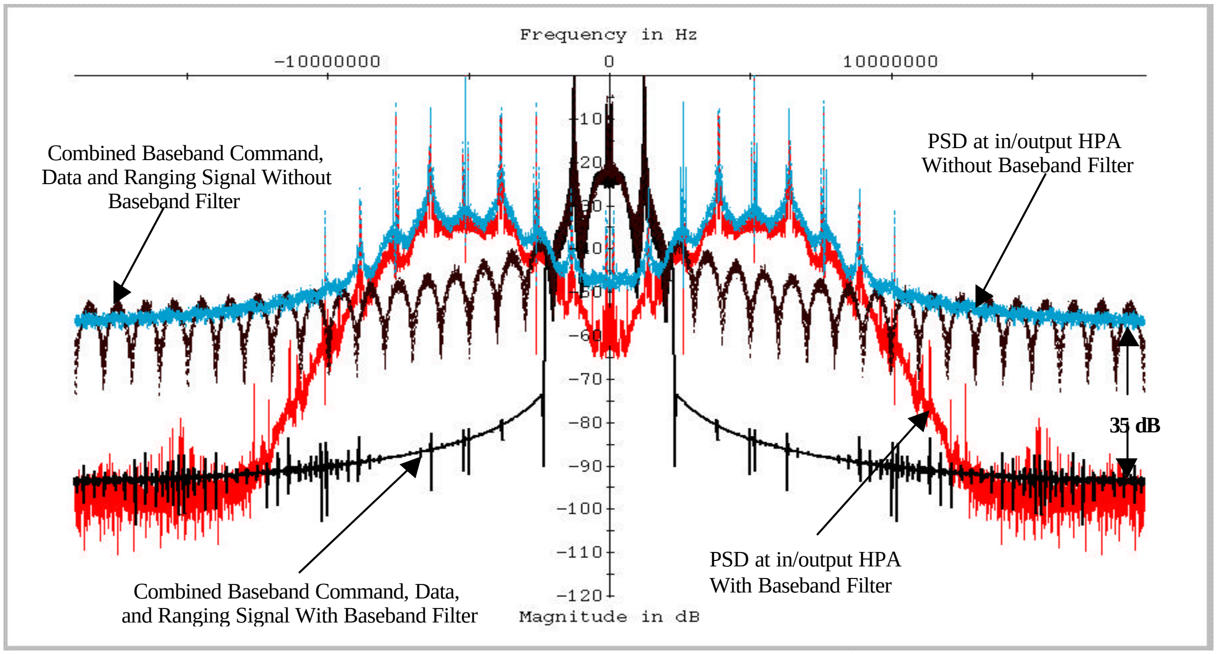


Figure C-2. A Computer Generated Emission Signature of the SATOPS Uplink

Table C-3. IMT-2000 Receiver Data

IMT-2000 Platform	Receiver Interference Thresholds Plotted (dBm)	Receiver Antenna Height (Meters)	Receiver Antenna Gain (dBi)
Fixed Base Stations	<-121 -111 to -121 -101 to -111 -91 to -101 -81 to -91 -71 to -81 > -71	40	17
Mobiles and Portables	<-105 -95 to -105 -85 to -95 -75 to -85 >-75	1.5	0

Table C-4 lists the SATOPS uplink parameters used in the assessment. Transmitter maximum powers in the table represent the maximum transmitter capability of the high power amplifier connected to the terminal. A minimum power of 100 watts was selected under the assumption that link closure with sufficient margin can be achieved at this level. It is recognized that in some instances a minimum transmit power of 250 watts, 500 watts, or even 1 kW is desired for adequate link margin. However, results from the overlays will indicate that several dB of variation in the transmit power assumptions will not change the conclusions that can be drawn from the data. Antenna off-axis gains were determined from antenna patterns provided by the Aerospace Corporation. Antenna off-axis gain at the horizon was calculated assuming 3, 5, and 10-degree minimum elevation angles. As discussed in the approach, these levels are considered to be within the range of acceptable value from an operations concept perspective. Figures C-3 through C-6 are computer generated antenna patterns for the 60, 46, 33, and 23 foot antenna diameters. These figures were used to calculate the off-axis antenna gains at the 3, 5, and 10-degree minimum elevation angles.

Table C-4. SATOPS Model Inputs

Terminal	TX Powers (watts)	Antenna Diameter (ft)	Antenna off-axis gain (dBi)			Effective Isotropic Radiated Power (EIRP) (dBm)		
			3º	5º	10º	3º	5º	10º
CTS	2.25K max/100 min	33	8	5	3	72/58	69/55	67/53
NHS	10K max/100 min	60 (A)	24	17	12	91/71	87/67	82/62
	2.5K max/100 min	46 (B)	18	5	3	82/68	69/55	67/53
	1K max/100 min	33 (DLT)	8	5	3	68/58	65/55	63/53
OAS	2000 max/100 min	51 (DLT)	18	5	3	81/68	68/55	66/53
EVCF	2.25K max/100 min	23	23	16	12	87/73	80/66	76/62

(A), (B), and (DLT – Data Link Terminal) are designators used to differentiate between unique site locations.

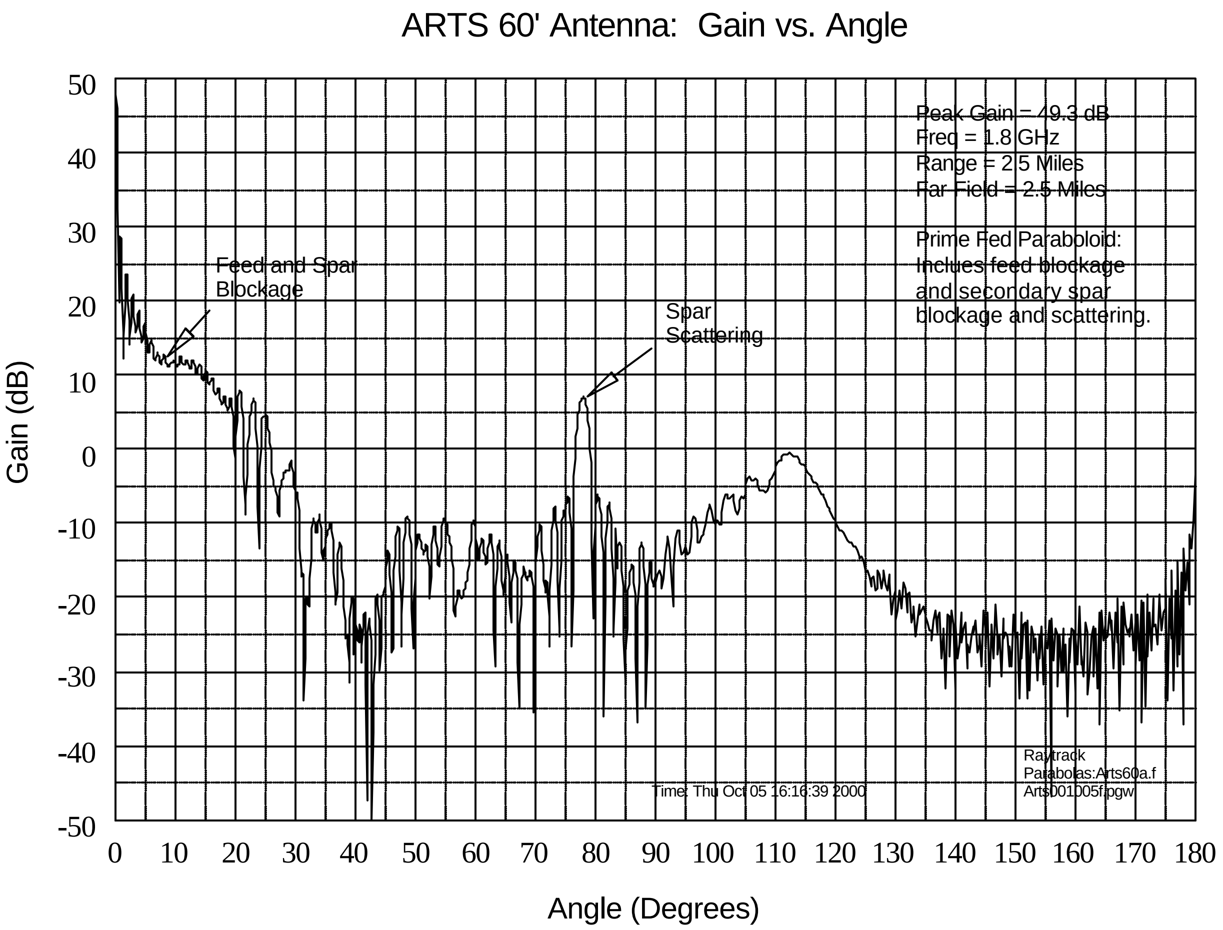


Figure C-3. Computer Generated Antenna Pattern for the Automated Remote Tracking Station (ARTS) 60-foot Antenna Diameters

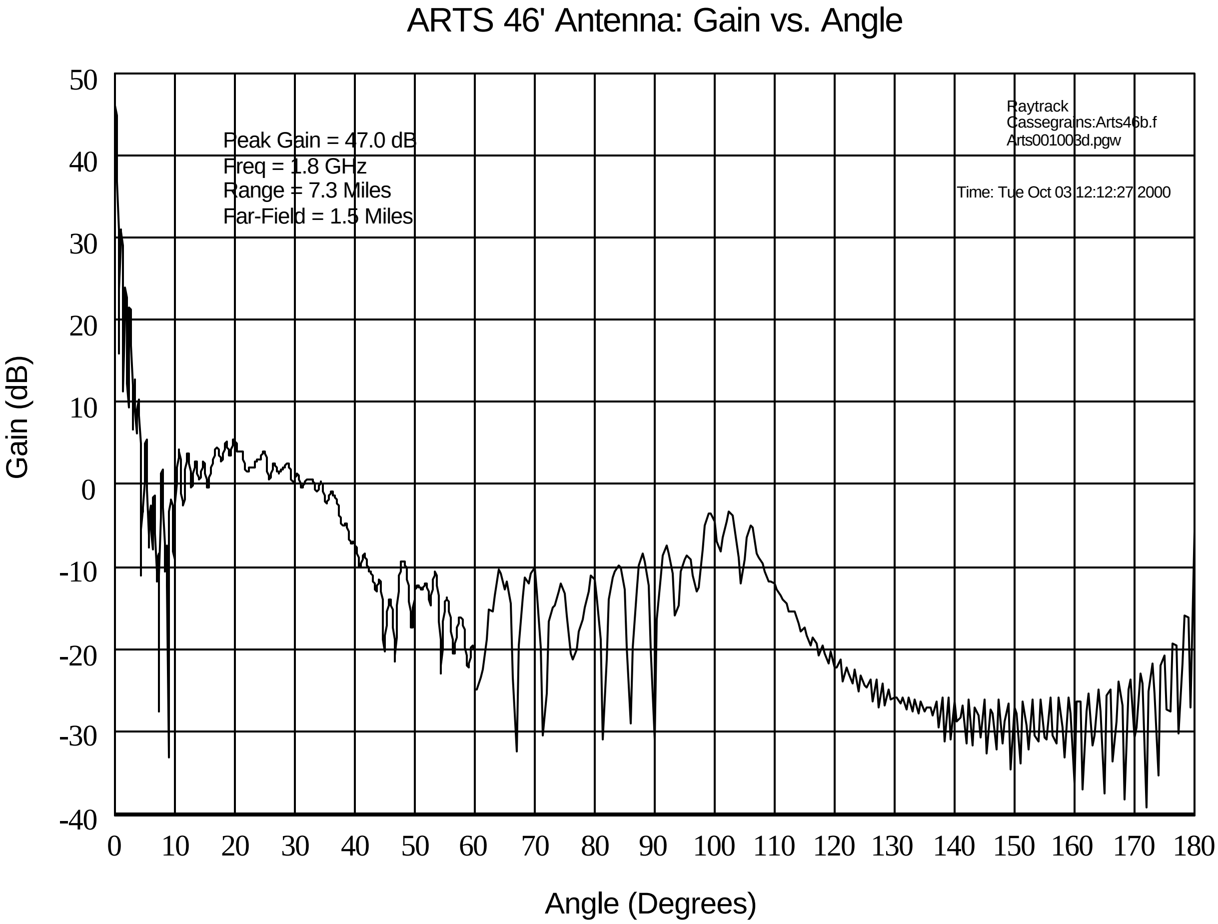


Figure C-4. Computer Generated Antenna Pattern for the 46-foot Antenna Diameters

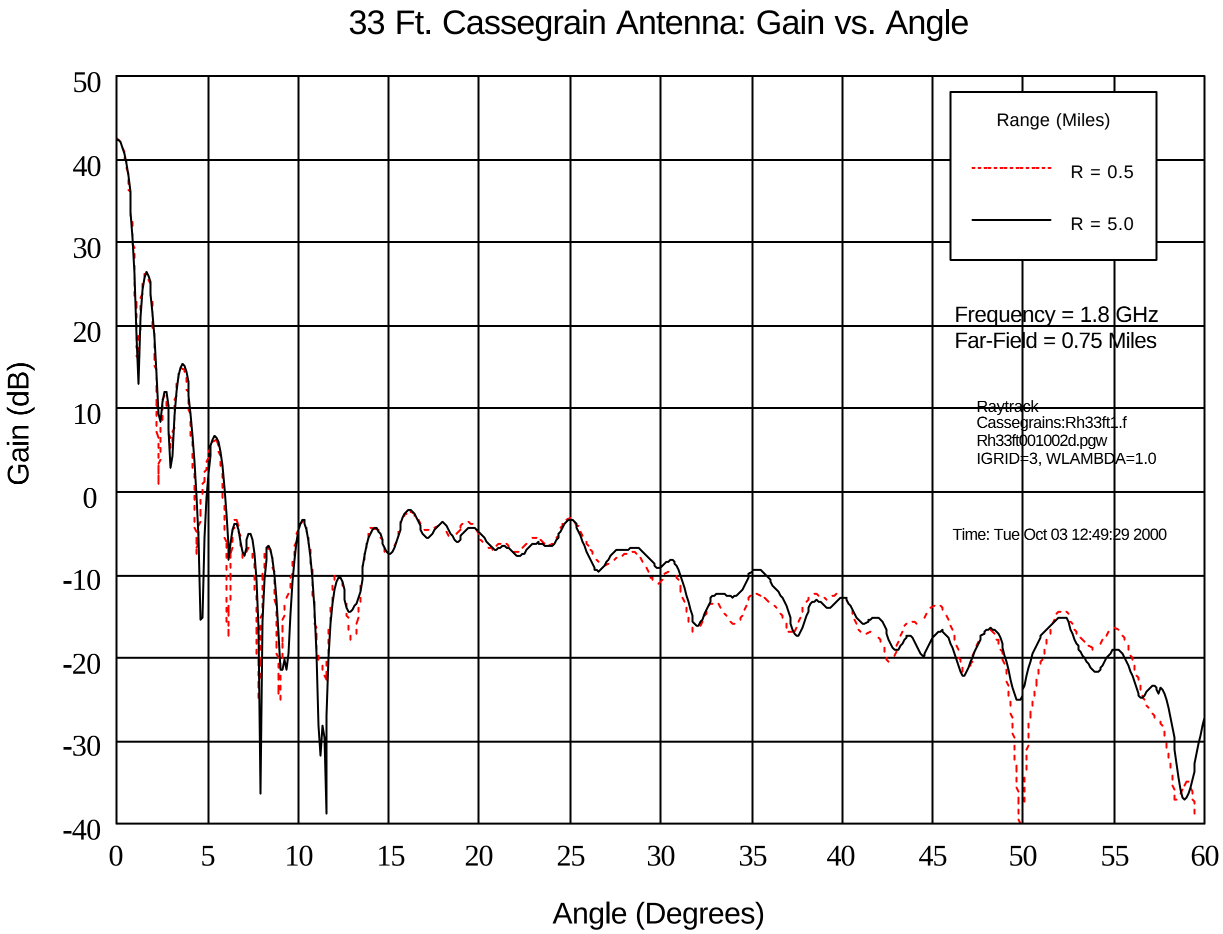


Figure C-5. Computer Generated Antenna Patterns for the 33-Foot Antenna Diameters

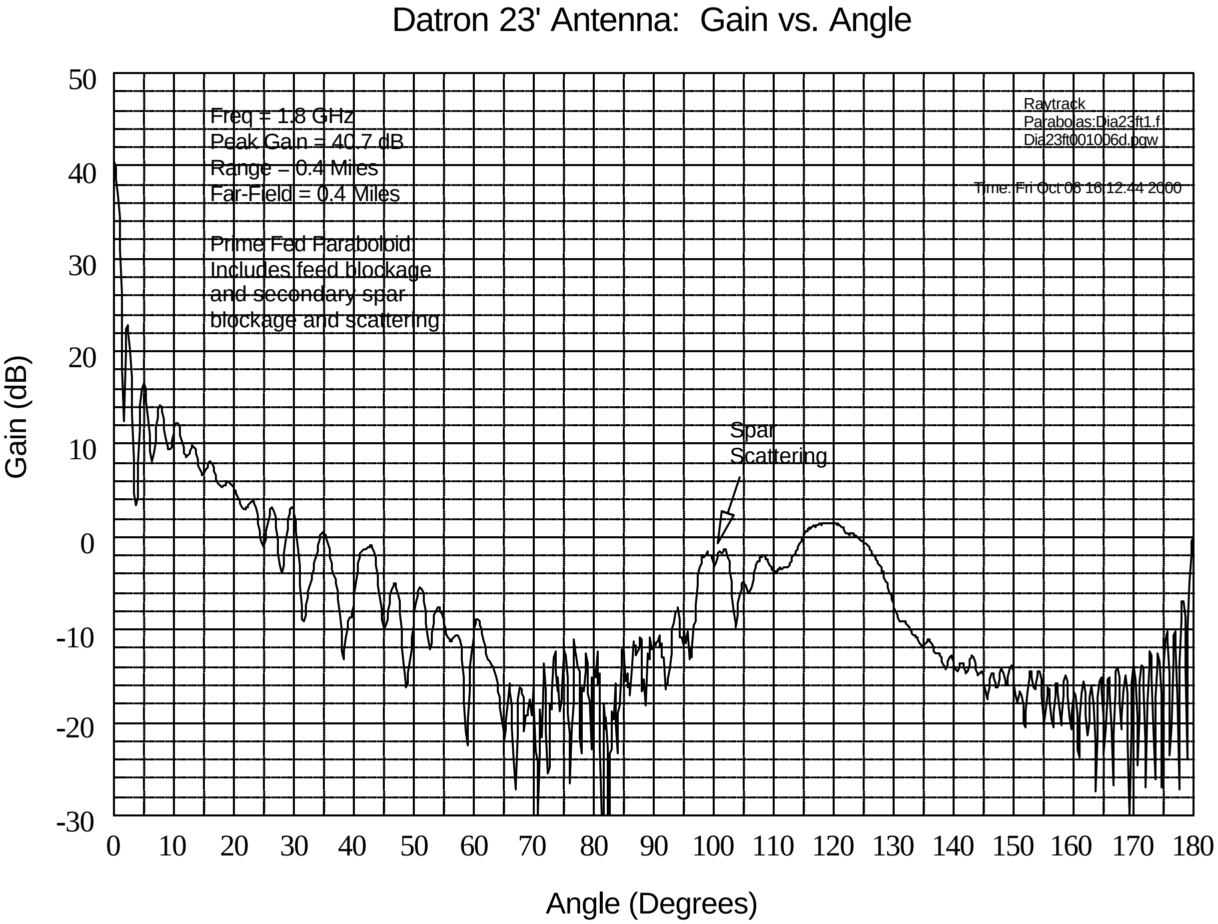
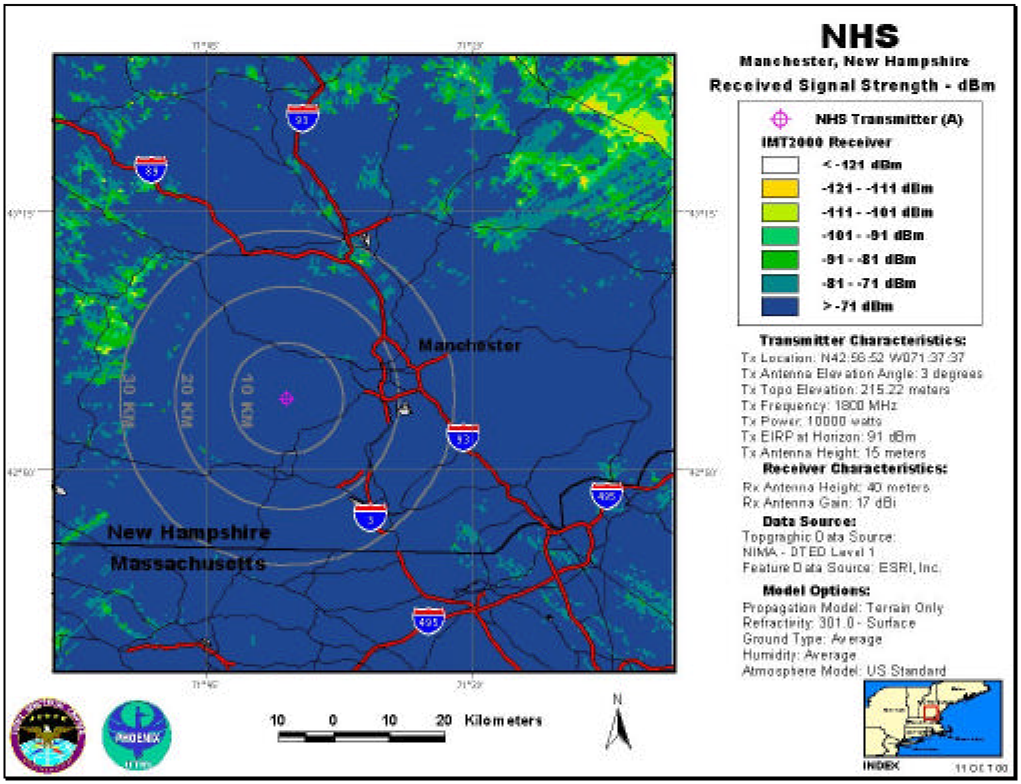


Figure C-6. Computer Generated Antenna Patterns for the 23-Foot Antenna Diameters

C.4 RESULTS

Results of the signal level predictions for the four sites analyzed: CTS, NHS, OAS, and EVCF are contained in Attachment 1. Three-dimensional topographic displays of the regions surrounding the sites are included to illustrate the relationship between terrain and predicted received signal level. Several plots are included within this section for discussion. A legend in the upper right corner of the overlays defines the IMT-2000 received threshold plotted. It should be noted that the –121 dBm threshold, which is depicted as white in the legend, is portrayed as yellow on the overlays. Below the legend are all of the input parameters used to generate the overlay.

Figure C-7 is an overlay for the worst-case conditions at NHS: maximum transmitter power (10 kW), and minimum elevation angle (3 degrees). Worst case overlay conditions apply to the IMT-2000 base stations vice the mobiles due to the increased antenna height (40 meters) and higher antenna gain (17 dBi) associated with the fixed sites. As shown in the figure, no region within the 70 X 70 km area shown meets the -121 dBm threshold. In fact, virtually all of the area depicted in the overlay experiences levels in excess of –71 dBm, well in excess of what might be considered a reasonable threshold level for the IMT-2000 receivers. Figure C-8 depicts the coverage for the same site under best case transmitter conditions, 100 watt transmitter power, and a 10-degree minimum elevation angle. While there is a noted reduction in the region exposed to levels in excess of –71 dBm, there is still no area that meets or even approaches the -121 dBm threshold specified. Figure C-9 depicts the best case overall (from an interference perspective) in that it depicts signal levels to a mobile receiver (reduced antenna height and antenna gain) at the lowest SATOPS transmit power and highest antenna elevation angle. Under these conditions, significant improvement is noted from the previous overlays; however, there are still significant portions that extend out 70 km and beyond from the site that exceed the -105 dBm threshold.



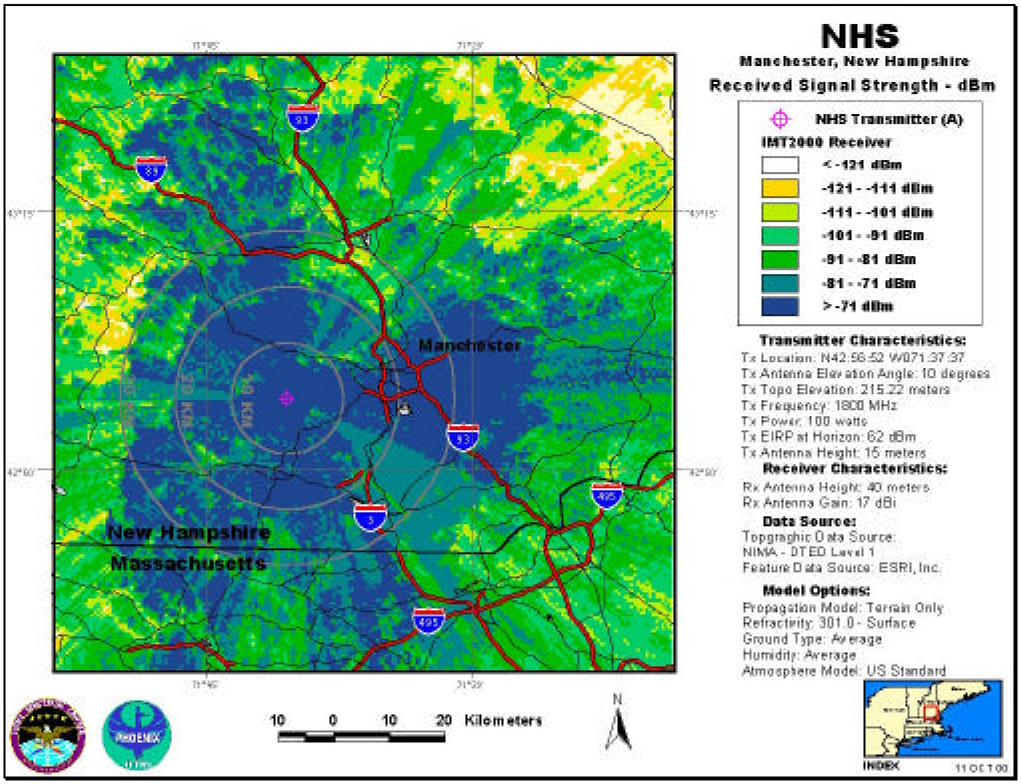
Transmitter Characteristics:
Tx Location: N42:56:52 W071:37:37
Tx Antenna Elevation Angle: 3 degrees
Tx Topo Elevation: 215.22 meters
Tx Frequency: 1800 MHz
Tx Power: 10000 watts
Tx EIRP at Horizon: 91 dBm
Tx Antenna Height: 15 meters

Receiver Characteristics:
Rx Antenna Height: 40 meters
Rx Antenna Gain: 17 dBi

Data Source:
Topgraphic Data Source:
NIMA - DTED Level 1
Feature Data Source: ESRI, Inc.

Model Options:
Propagation Model: Terrain Only
Refractivity: 301.0 - Surface
Ground Type: Average
Humidity: Average
Atmosphere Model: US Standard

Figure C-7. NHS-A, Antenna Elevation Angle: 3°, Transmitter Power: 10,000 W, IMT-2000 Base Station



Transmitter Characteristics:
Tx Location: N42:56:52 W071:37:37
Tx Antenna Elevation Angle: 10 degrees
Tx Topo Elevation: 215.22 meters
Tx Frequency: 1800 MHz
Tx Power: 100 watts
Tx EIRP at Horizon: 62 dBm
Tx Antenna Height: 15 meters

Receiver Characteristics:
Rx Antenna Height: 40 meters
Rx Antenna Gain: 17 dBi

Data Source:
Topgraphic Data Source:
NIMA - DTED Level 1
Feature Data Source: ESRI, Inc.

Model Options:
Propagation Model: Terrain Only
Refractivity: 301.0 - Surface
Ground Type: Average
Humidity: Average
Atmosphere Model: US Standard

Figure C-8. NHS-A, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Base Station

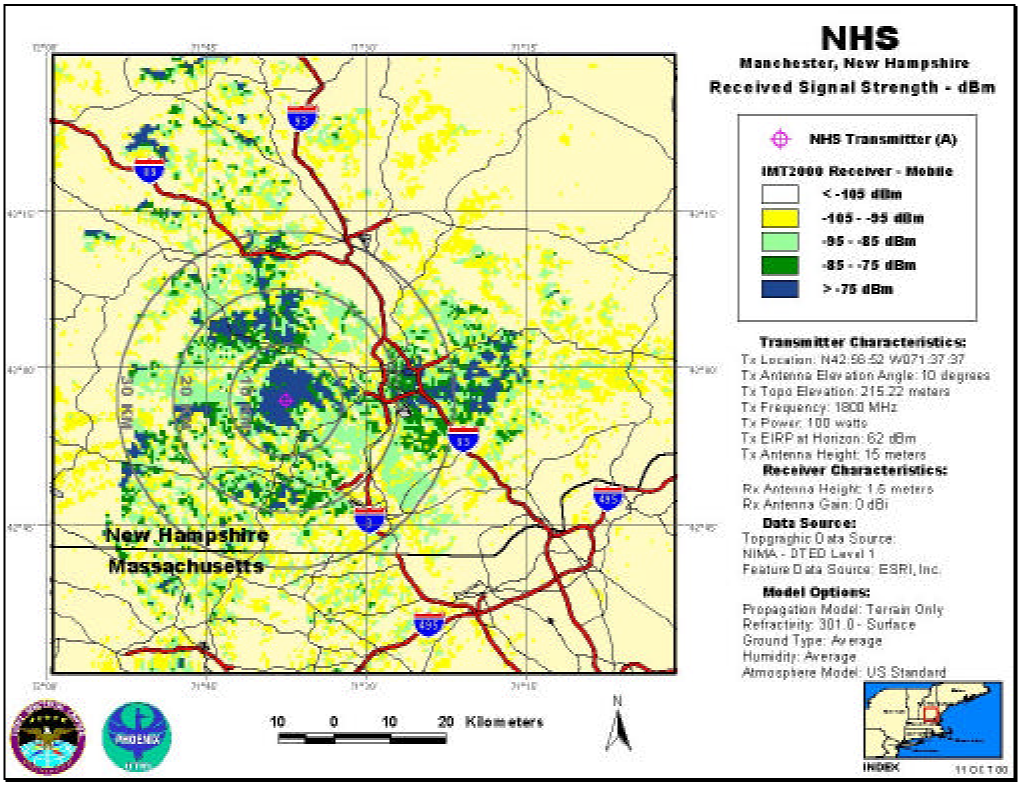


Figure C-9. NHS-A, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station

A review of the other sites analyzed produces similar results. Figure C-10 represents worst-case SATOPS uplink conditions (maximum power, low elevation angle) for the OAS site. Like the NHS overlays, signals in excess of -71 dBm extend well beyond 70 km from the uplink terminal. Under these conditions, electromagnetic interference (EMI) from OAS extends well beyond the highly populated and highly desirable market regions of Oakland and San Francisco. Even under best case conditions (10 degrees and 100 watts), Figure C-11 illustrates that the areas in excess of -121 dBm extend well over 75 km from the site. Figure C-12 depicts impact to IMT-2000 mobile users under best case SATOPS uplink conditions. Like the NHS case, this represents the smallest potentially affected area. However, the region impacted still encompasses highly desirable regions from an IMT-2000 market perspective.

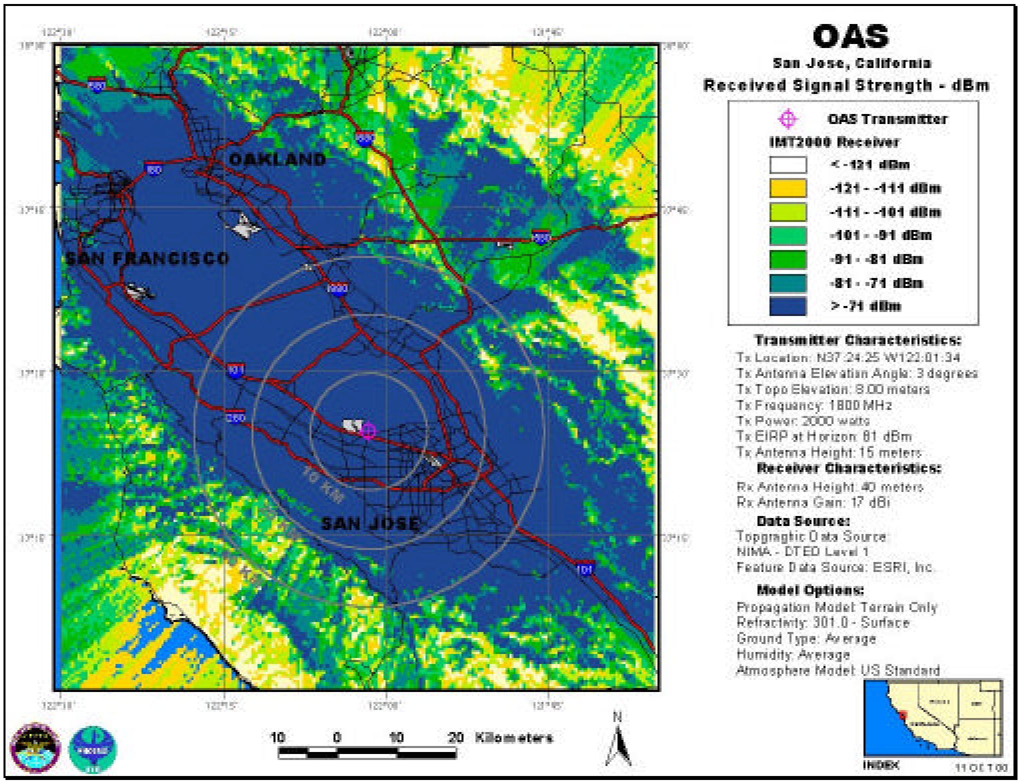


Figure C-10. OAS, Antenna Elevation Angle: 3°, Transmitter Power: 2,000 W, IMT-2000 Base Station

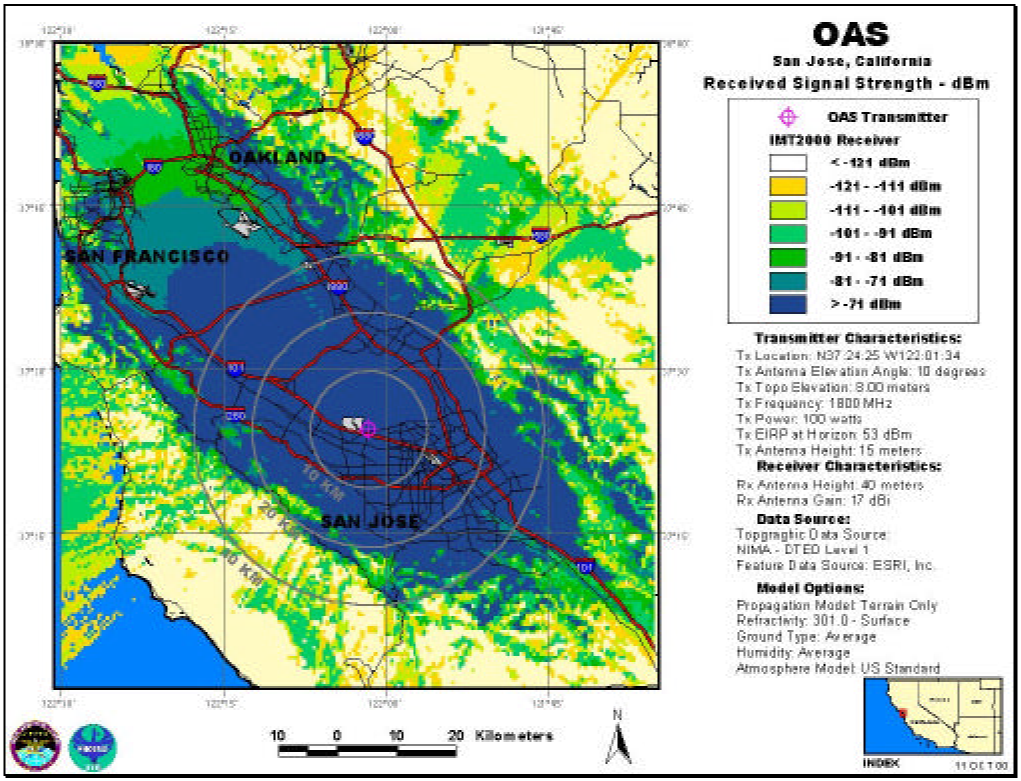


Figure C-11. OAS, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Base Station

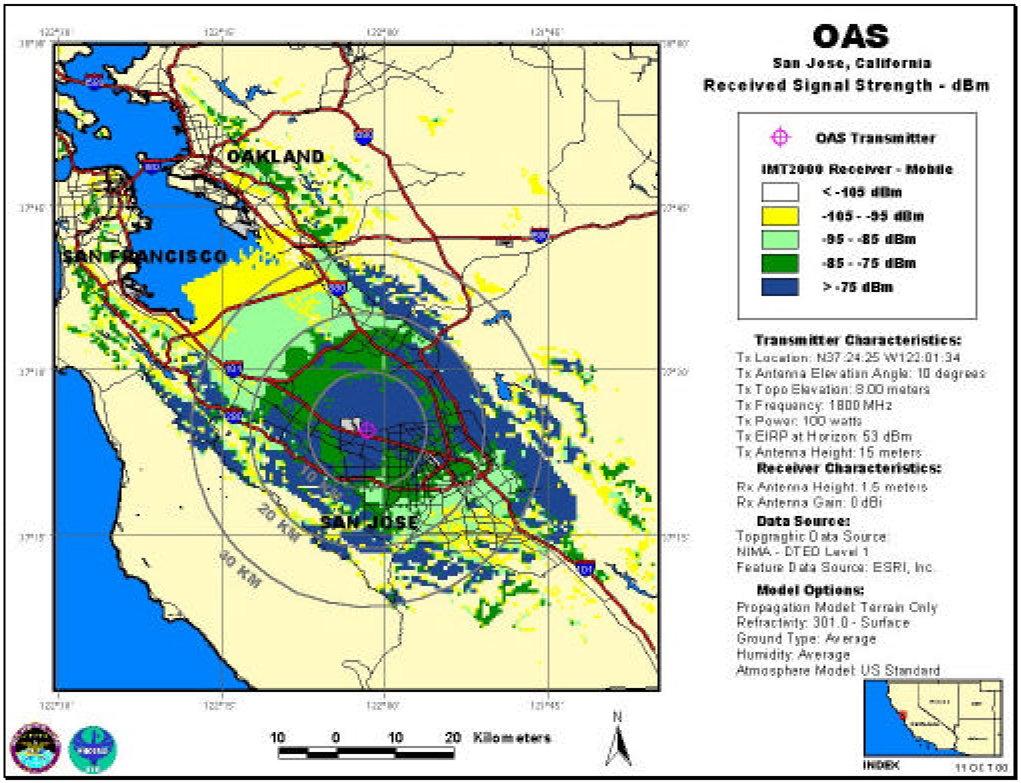


Figure C-12. OAS, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Moblie Station

It should be noted that the assessment assumes 360-degree coverage for the SATOPS antenna. While for many sites this is true (including NHS), there are some sites that do concentrate activities within specific azmiuth ranges. A follow-on effort to generate overlays that reflect more of the operations concepts for the sites would be beneficial. It is also worthy of note that a particular SATOPS uplink terminal only transmits on one channel at a time thereby lessening the impact to IMT-2000 users on adjacent operating frequencies. This fact, coupled with the specific antenna azimuth operations, allows for the possibility of sharing on a time/frequency basis.

C.5 BAND SEGMENTATION

Band segmentation schemes have been proposed that would separate Government use and IMT-2000 use into separate portions of the 1760-1850 MHz band. One such proposal is to allow SATOPS functions in the 1760-1805 MHz band and IMT-2000 operations in the 1805-1850 MHz band. Such a proposal serves to minimize the potential for electromagnetic interference (EMI) by maintaining a frequency separation between transmitters and receivers. Given that SATOPS functions currently support satellites operating throughout the 1761-1842 MHz band, a segmentation scheme alone would reduce but not eliminate the potential for EMI to IMT-2000 receivers. The potential for EMI would remain for those systems operating in the IMT-2000 portion of the spectrum until the requirement to support such satellites no longer existed. In some instances however, satellite programs are supported via two S-band channels. This introduces the added benefit of frequency flexibility and provides an EMI mitigation possibility if one of the two channels lies outside the IMT-2000 spectrum. Finally, for those satellites that have not yet been launched, the opportunity exists to outfit the vehicle with SATOPS transponders in the band segment allocated for TT&C.

To illustrate the impact of off-tuning the SATOPS uplink and IMT-2000 receivers on the relative size of the coordination regions, three sample overlays were generated for the New Hampshire B terminal operating at 2.5 kilowatts with a 10 degrees elevation angle. Figures C-13 through C-15 illustrate the coordination regions for IMT-2000 base station receivers assuming frequency separations of 4, 8, and 12 MHz respectively (1, 2, and 3 SATOPS uplink channels). Beyond 12 MHz, the uplink emission rolls off gradually such that additional frequency separation yields minimal benefit.

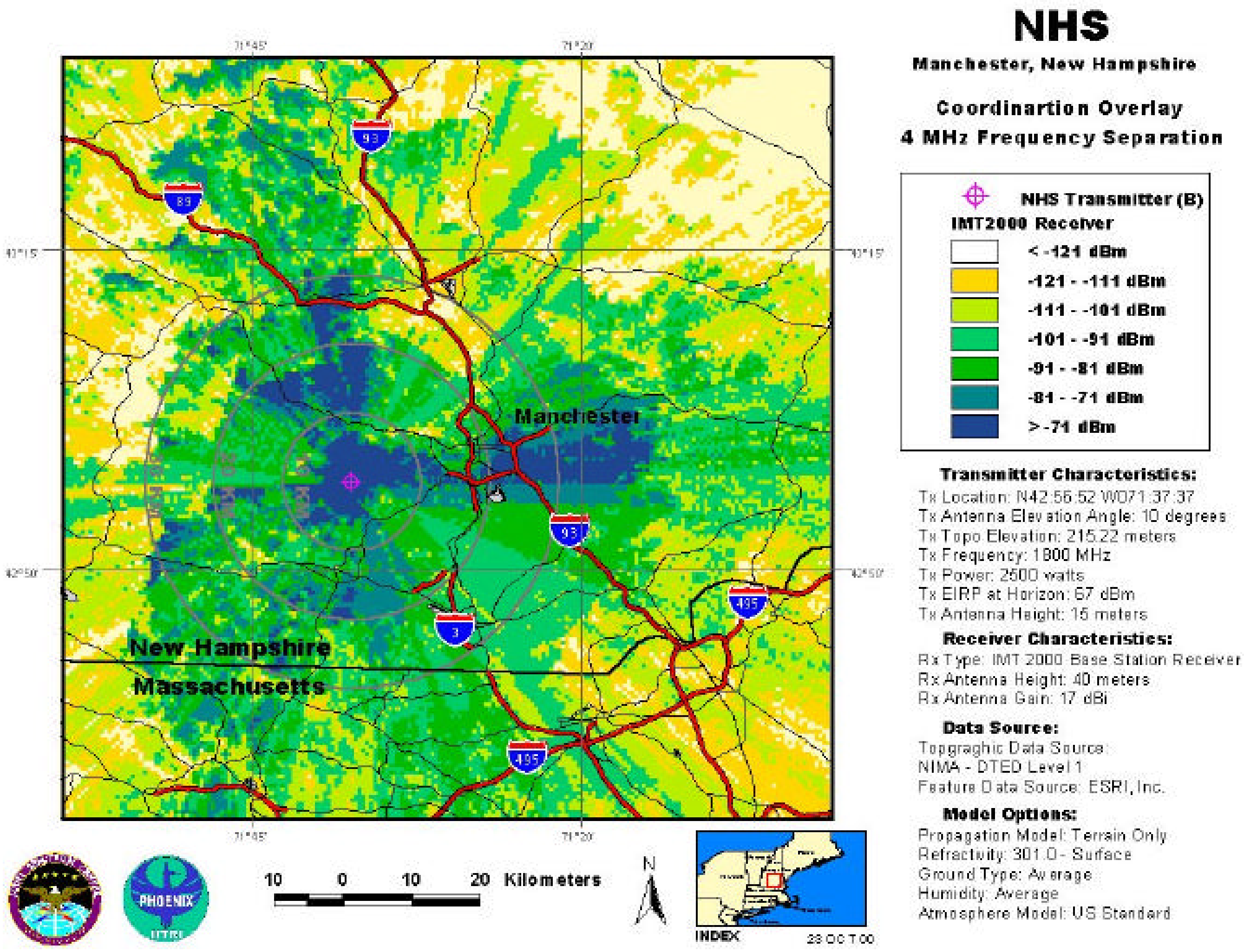
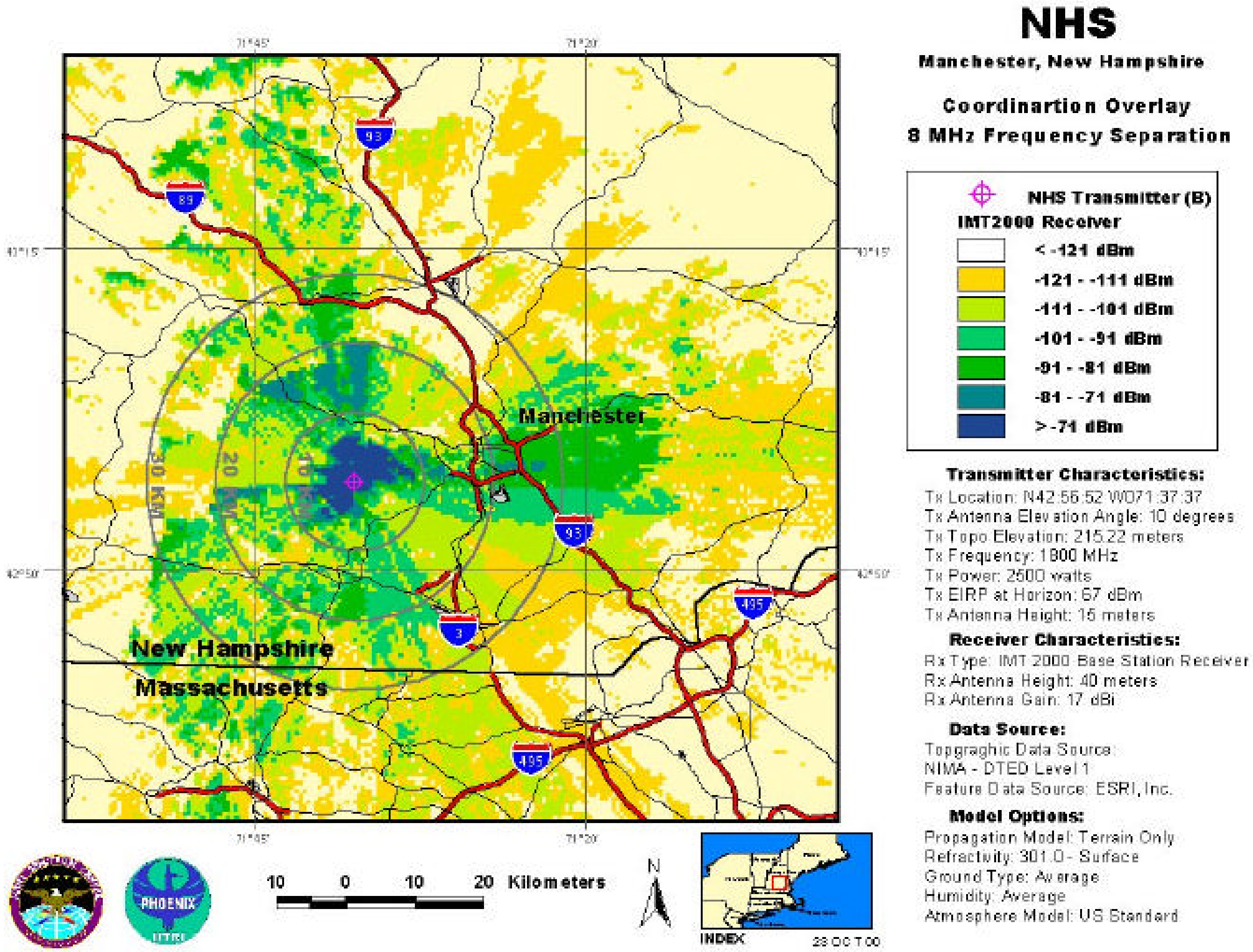


Figure C-13. Coordination Overlay for 4-MHz Frequency Separation



Transmitter Characteristics:

Tx Location: N42:56:52 W071:37:37
Tx Antenna Elevation Angle: 10 degrees
Tx Topo Elevation: 215.22 meters
Tx Frequency: 1800 MHz
Tx Power: 2500 watts
Tx EIRP at Horizon: 67 dBm
Tx Antenna Height: 15 meters

Receiver Characteristics:

Rx Type: IMT 2000 Base Station Receiver
Rx Antenna Height: 40 meters
Rx Antenna Gain: 17 dBi

Data Source:

Topgraghic Data Source:
NIMA - DTED Level 1
Feature Data Source: ESRI, Inc.

Model Options:

Propagation Model: Terrain Only
Refractivity: 301.0 - Surface
Ground Type: Average
Humidity: Average
Atmosphere Model: US Standard

Figure C-14. Coordination Overlay for 8-MHz Frequency Separation

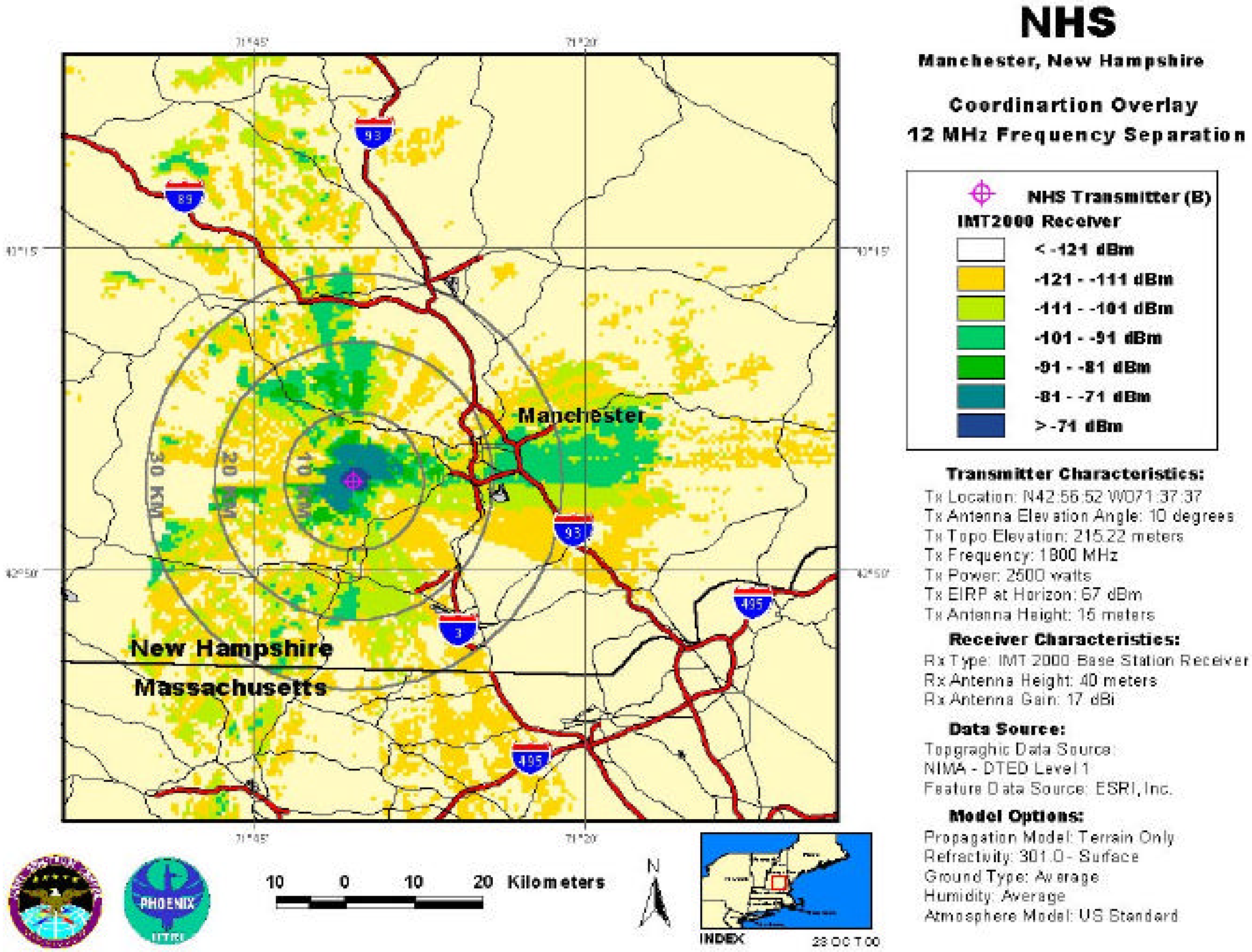


Figure C-15. Coordination Overlay for 12-MHz Frequency Separation

As can be viewed from the overlays, frequency separation clearly reduces the coordination regions, however, like other mitigation techniques discussed, it does not singly provide sufficient isolation between the systems to eliminate the potential for EMI. The limited benefit achieved through off-tuning is reflective of the typically wide/unfiltered emission spectra in the current SGLS signal structure, which is in part due to the unwanted spectral components generated via a class C amplifier. It is expected that the more spectrally efficient signal structures that are being considered for future SATOPS uplinks would yield greater benefit in a band segmentation scheme.

C.6 CONCLUSIONS

SATOPS uplink power management, antenna elevation angle restrictions, and frequency off tuning help to reduce the affected area around the SATOPS uplink transmitter. However, if coordination regions on the order of 10 to 20 km are desired, and IMT-2000 specified interference thresholds are to be met, an orders of magnitude decrease in the undesired signal level will be required. Additional measures for reducing the uplink power at the IMT-2000 receiver coupled with power management and antenna restrictions must be implemented to significantly limit the affected area surrounding the uplink site.

C.7 SATOPS UPLINK TO IMT-2000 RECEIVERS INTERFERENCE MITIGATION MEASURES

Based upon the results of the signal level predictions, it is apparent that additional signal attenuation is required if sharing between the services is desired. Potential mitigation techniques fall into one of three categories: measures implemented solely by the DoD SATOPS community, measures implemented solely by the IMT-2000 industry, and those techniques that require mutual implementation by both parties. The following measures are presented for discussion and consideration. Further analysis is warranted to address viability, cost, and implementation issues.

C.7.1 DoD EMI Mitigation Techniques

C.7.1.1 Relocation of the SATOPS Uplink Antennas and/or SATOPS Transmission Off-loading

Many of the current SATOPS terminals around the world are located in remote areas such as Diego Garcia and Thule, Greenland. It is expected that these regions will have a relatively low IMT-2000 user density. There are, however, several stations, such as New Hampshire or Sunnyvale, located near population centers. For sites such as these, it may be useful to consider moving the antennas themselves to more remote locations with lower population densities that are less desirable from an IMT-2000 market perspective. Similarly, where satisfactory visibility can be achieved, it may be possible that some of the operations currently performed by terminals in populated areas could be off-loaded to the more remote terminals. The signals to be radiated or received by these antennas could be fed to/from the stations by fiber optic or cable.

C.7.1.2 Reduction of the Out-of-Beam Energy of the SATOPS Antennas

Assuming that the mainbeam emissions are highly focused in the SATOPS antennas, some control of the radiation in the direction of the victim receivers would be beneficial. The most common approaches to this are (1) antenna elevation angle restrictions and (2) intentional signal blockage and antenna redesign.

SATOPS Antenna Elevation Angle Restrictions. Like power management, restricting the minimum elevation angle serves to limit the power at the horizon and hence reduce the undesired signal into the IMT-2000 receiver. As illustrated in the overlays, a 10-degree minimum elevation angle reduced the size of the affected areas. However, even when coupled with power management, these measures are insufficient to reduce EMI regions to expected acceptable levels. A study of the operations impact for going to a 10-degree minimum elevation angle should be conducted. Where acceptable, this limitation would serve to reduce the EMI potential and promote sharing.

Signal Blockage and Antenna Redesign. Intentional signal blockage can be achieved via a cylinder surrounding the dish to reduce spillover, modification of the feed, or modification of the illumination taper to reduce sidelobes at the expense of gain.

The use of RF absorbing materials around struts and at the back of the antenna to reduce secondary reflection would also help eliminate sidelobe emissions. Redesign of the antennas to a type such as an offset parabola, which has inherently lower sidelobes is also worthy of consideration. Apart from the antenna design and structure, radar fences, screening, and even the use of vegetation at the site can be effective measures to block emissions in specific directions. These and the other measures discussed for controlling signals outside of the mainbeam are worth additional consideration to weigh cost versus benefit.

C.7.1.3 SATOPS Power Management

SATOPS transmit power capabilities typically vary over a wide range from as low as 100 watts to as much as 10 kw. The high-power transmissions are typically reserved for anomalies but are also radiated periodically for system check-out and training. Link closure with adequate margin can typically be achieved at powers in the 100 to 500 watt range. As indicated in the signal level predictions, power management does not in of itself solve the EMI problem; however, it does reduce the size of the affected regions. Follow-on studies should be performed to determine the minimum acceptable levels required for maintaining satisfactory link closure. Operations at these levels would be one step toward reducing the EMI to IMT-2000 receivers.

C.7.2 IMT-2000 EMI Mitigation Techniques

C.7.2.1 Establishment of Keep-Out Zones

Short of complete frequency separation, there is a potential for EMI to a mobile user (or fixed base station) if it is allowed to operate in proximity to an SATOPS uplink transmitter. The signal level overlays clearly show the potential size of the affected areas. The possibility of some keep-out zone, even if only a few kilometers surrounding the site, should be considered to help mitigate the most challenging close in interactions.

C.7.2.2 Base Station Antenna Nulling

It is expected that IMT-2000 antenna implementation may be similar to the current cellular/PCS designs; three direction antenna segments each covering a 120 degree sector. This scheme introduces the possibility to add an additional highly directive antenna in the direction of the SATOPS terminal and to use that signal to null out the received signals on the broadbeam antenna in the direction of the SATOPS terminal. The hole in coverage created by this scheme could then be filled via an alternate antenna at a location such that a mainbeam interaction with the SATOPS terminal is avoided.

C.7.2.3 Polarization Discrimination

Polarization discrimination mitigation takes advantage of the fact that the mobile signals are linearly polarized, whereas the SATOPS uplinks are circularly polarized. By measuring the received polarization and cross polarizing the IMT-2000 base station to that signal, a significant reduction in interference is achievable (20 dB) with only a 3-dB reduction to the mobile signal. This proposal obviously requires an investment in technology by the IMT-2000 community and may be practical on a limited scale for base stations in specific problem areas.

C.7.3 Mutual EMI Mitigation Techniques

Cooperative scheduling is an attractive EMI mitigation technique that offers a potential benefit if mutual agreement and coordination with the IMT-2000 industry can be achieved. Cooperative scheduling is not unlike band segmentation in that both approaches look toward frequency separation between the systems as a technique for minimizing the potential for EMI. Note however the significant distinction between cooperative scheduling, which assumes sharing of the entire SGLS uplink band via real-time frequency deconfliction, and band segmentation, which assumes separation of systems into distinctly separate portions of the spectrum. Unlike band segmentation, cooperative scheduling addresses EMI issues associated with uplinks to currently flying systems for which only one S-band channel is available for TT&C. In these instances, there is essentially no flexibility in terms of spectrum use from the SATOPS perspective.

Cooperative scheduling takes advantage of the fact that SATOPS operations only use a limited amount of spectrum at any given instant in time. That, coupled with the specific antenna pointing required for a satellite contact, limits the affects on the environment. Therefore, at any instant, only a relatively small portion of the IMT-2000 network maybe affected. The concept behind cooperative scheduling is to allow the IMT-2000 network to dynamically assign spectrum usage to the network around the SATOPS uplink transmissions. This technique would require software enhancements and dynamic switching capabilities for the IMT-2000 systems. It also assumes that the IMT-2000 switching algorithm is fed information on the SATOPS uplink schedule either in advance via pre-coordination, in real-time via landline, or by monitoring the environment for SATOPS signal use. The requirement to pass SATOPS scheduling information to IMT-2000 service providers in turn raises operations securities issues that need to be addressed. While this mitigation technique is not without its challenges, it takes advantage of the SATOPS unique time/frequency use of the electromagnetic spectrum and, therefore, could be one of the more effective techniques to reduce EMI to the IMT-2000 users.

C.7.4 Summary

Further study is required to quantify the benefit of the aforementioned mitigation measures. Figures C-16 and C-17 are provided to illustrate the benefit of mitigation techniques that provide an additional 50 dB of attenuation in the direction of the victim receiver. Note that under the worst case conditions for NHS, the affected area improvement is notable but still considerably large. By contrast, the coordination area for the NHS DLT under best case conditions (10 degrees and 100 watts) is reduced to only a very few small regions local to the uplink site.

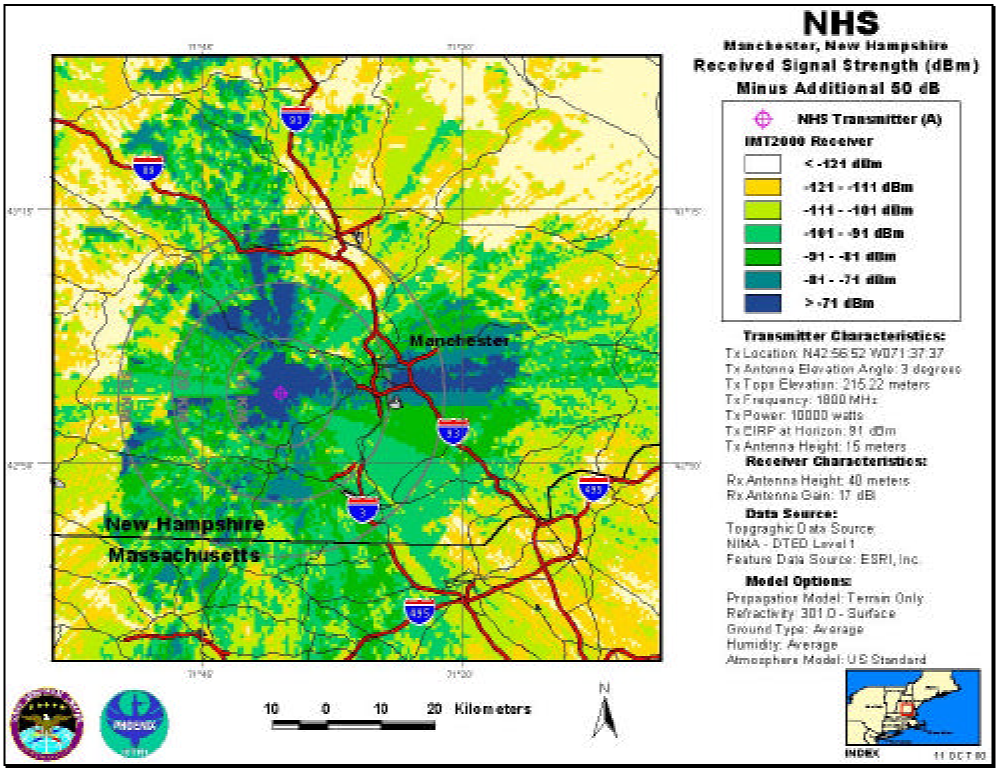


Figure C-16. NHS-A, Antenna Elevation Angle: 3°, Transmitter Power: 10,000 W, IMT-2000 Base Station, Plus an Additional 50 dB of Signal Attenuation

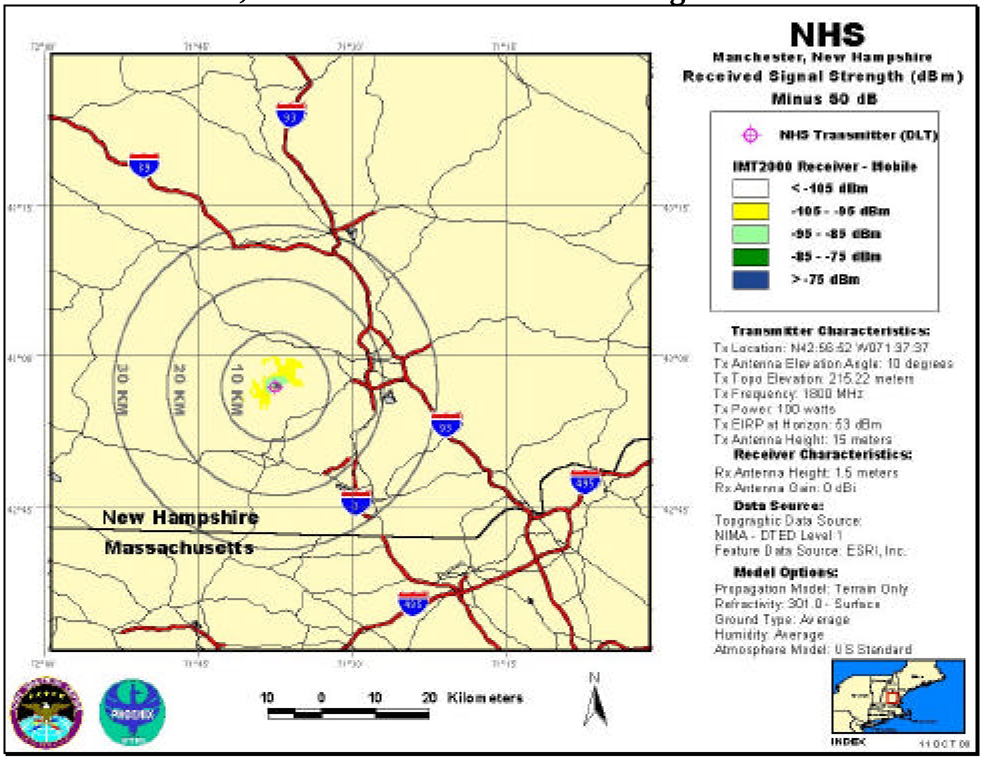


Figure C-17. NHS-DLT, Antenna Elevation Angle: 10°, Transmitter Power: 100 W, IMT-2000 Mobile Station, Plus an Additional 50 dB of Signal Attenuation

APPENDIX D – POTENTIAL FOR SHARING BETWEEN IMT-2000 AND TACTICAL RADIO RELAY IN THE 1755-1850 MHZ FREQUENCY BAND

A large number of existing Department of Defense (DoD) line-of-sight (LOS) microwave (MW) systems operate in the 1755-1850 MHz frequency band. This appendix addresses the potential for interference between the IMT-2000 systems and the DoD tactical radio relay systems.

The LOS MW systems operating in the band are too numerous to analyze individually, and many of these systems do not have unique requirements limiting the systems to frequencies below 3 GHz. However, one class of systems with requirements constraining operations to frequencies near the 1755-1850 MHz band are the DoD tactical radio relay systems, and these systems were analyzed in the assessment.

The military services require efficient methods of exchanging large quantities of digital data throughout the battlefield. The increased use of computers, digital video, and facsimile equipment in command and control, intelligence, and logistics will generate more data in the future. The military radios are deployable, point-to-point radio systems using low-to-moderate gain antennas. The military tactical radio relay equipment uses broad beamwidth antennas for quick link setup during deployments. The movement of the lightweight, flexible masts that support the antennas or the movement of shipboard antennas preclude the use of narrowbeam antennas. The requirements for low/moderate power levels for the transportable radios and the broad beamwidth antenna limits applicable frequency band to below 3 GHz. The primary DoD tactical radio relay systems operating in the 1755-1850 MHz band are the US Army Mobile Subscriber Equipment (MSE) and the US Navy Digital Wideband Transmission System (DWTS).

D.1 ANALYSIS APPROACH

The DoD tactical radio relay systems potential for sharing the 1755-1850 MHz frequency band with the IMT-2000 systems was investigated on a one-to-one basis. A distance separation required to protect each of four radio relay systems from each of the four candidate IMT-2000 systems and each of the four candidate IMT-2000 systems from the four radio relay systems was determined. The IMT-2000 mobiles and base stations (including main-beam and side-lobe antenna gains) were analyzed versus the radio relay main-beam and side-lobe antenna gains. The ship-based DWTS uses an omnidirectional antenna, and the DWTS was analyzed at the highest and lowest transmitter power setting.

D.2 TACTICAL RADIO RELAY SYSTEM DESCRIPTIONS

MSE. The MSE is a multi-band, tactical LOS radio system, more accurately described as a "system-of-systems," because it is composed of several components, each of which are fully operational systems. The individual components that make up the MSE are dependent upon several portions of the radio frequency spectrum (e.g., 30-88 MHz, 225-400 MHz, 1350-1850 MHz, and 14.5-15.35 GHz). The inability of any of these components to operate successfully would result in the failure of the overall system. One critical component of the MSE, the AN/GRC-226(V)2 radio, operates in the 1755-1850 MHz frequency band. It is used to connect radio access units to the node center switch of the network. Operational use plans call for 465 units per Army Corps, giving a total of 2,325 units for five Corps. The AN/GRC-226(V)2 is a digital radio that can tune to any of 4000 available channels, spaced at 125 kHz, between 1350-1850 MHz; however, due to the allocation of most of this band to other services, users rarely have access to spectrum outside of 1350-1390 MHz and 1710-1850 MHz. The AN/GRC-226(V)2 requires a 50.125-MHz minimum frequency separation between the site transmitter and receiver for a duplex link. The technical parameters of the AN/GRC-226(V)2 used in the analysis are presented in Table D-1.

Table D-1. AN/GRC-226 (V) Parameters (J/F 12/6102/2)

Frequency range	1350 – 1850 MHz
Transmit power	0.5 - 5 W
Emission Bandwidth (MHz)[a]	1.25 (-3dB), 3.5 (-20dB), 10.55 (-60dB)
Antenna gain	20 dBi (MB), 11 dBi (20-90 deg), 2 dBi (90-180 deg)
Antenna height	30 m
Receiver bandwidth (MHz)[a]	0.85 (-3dB), 1.6 (-20dB), 4.4 (-60dB)
Receiver noise figure	8 dB
Receiver sensitivity	-93 dBm @ BER = 10E–5 (S/N = 14 dB)
Receiver noise power	-107 dBm
Interfering signal threshold	-113 dBm
Cable losses	2.4 dB (NPT calc)
Waveform	2M40F9W*, 256 – 2048 kbps MSK
[a] 2048 kbps	

HCLOS. The High Capacity LOS (HCLOS) radio system is expected to eventually replace the AN/GRC-226(V)2 radios in the MSE for the Area Common User System (ACUS). The HCLOS radio, the AN/GRC-245(V), operates in the 225-400 MHz and 1350-2690 MHz bands with increased spectral efficiency and higher data rates compared to the current radio. The AN/GRC-245(V) requires a 50.125-MHz minimum frequency separation between the site transmitter and receiver for a duplex link. The technical parameters of the AN/GRC-245(V) used in the assessment are presented in Table D-2.

Table D-2. AN/GRC-245 (V) Parameters (J/F 12/7601)

Frequency range	1350 – 2690 MHz
Transmit power	31 mW - 1.6 W
Emission Bandwidth (MHz)[a]	2.0 (-3dB), 2.9 (-20dB), 7.2 (-60dB)
Antenna gain	23 dBi (mainbeam)
Antenna height	30 m
Receiver bandwidth (MHz)[a]	6.7 (-3dB), 8.1 (-20dB), 10.0 (-60dB)
Receiver noise figure	7 dB
Receiver sensitivity[a]	-86 dBm @ 8192 Kb/s and BER = 10E-5
Receiver noise power[a]	-99 dBm
Interfering signal threshold[a]	-105 dBm
Cable losses	4 dB @ 1850 MHz
Waveform	2M50W1D**,320-8256 kb/s, 32 TCM, rate 4/5 code

[a] 8256 kbps

<u>DWTS</u>. The DWTS is a LOS tactical radio system providing point-to-point (shore based AN/MRC-142), ship-to-ship (ship based AN/SRC-57) and ship-to-shore (AN/SRC-57 and AN/MRC-142 or the Army AN/GRC-226) communications. The DWTS provides communications vital to the Commander Joint Task Force (CJTF), Commander Amphibious Task Force (CATF), Commander Landing Force (CLF), Amphibious Forces afloat, and US Forces ashore. The system provides afloat and ashore commanders with entry into the Global Command and Control System – Maritime (GCCS-M) to ensure common access to intelligence, mapping, order of battle, and logistics information. The DWTS provides data transmissions for Battlegroup (BG) planning, video tele-conferences, BG e-mail connectivity, internet connectivity and intra-BG telephone connectivity. DWTS provides tactical digital wideband transmissions for voice, video, and data to support landing force command elements to include Marine regiment or Expeditionary Unit and higher and Army brigade and higher. The DWTS consists of two components, the shore based USMC AN/MRC-142 and the ship based US Navy AN/SRC-57.

<u>AN/MRC-142</u>. The shore based component of the DWTS, the AN/MRC-142, typically uses the frequency bands 1350-1390 MHz, 1432-1435 MHz, and 1710-1850 MHz. In addition, the AN/MRC-142 ship-to-shore links have further frequency restrictions caused by ship-based interference to the AN/SRC-57 located on ships. The AN/MRC-142 requires a 62-MHz minimum frequency separation between the site transmitter and receiver for a duplex link. The technical parameters of the AN/MRC-142 used in the evaluation are presented in Table D-3.

Table D-3. AN/MRC-142 Parameters (J/F 12/6461)

Frequency range	1350 – 1850 MHz
Transmit power	3.0 W
Emission Bandwidth (MHz)	0.4 (-3dB), 1.05 (-20dB), 3.15 (-60dB)
Antenna gain	20 dBi (mainbeam), 6.3 dBi (26 deg)
Antenna height	30 m
Receiver bandwidth (MHz)	0.8 (-3dB), 1.0 (-40 dB), 4.4 (-60 dB)
Receiver noise figure	8 dB
Receiver sensitivity	-93 dBm BER = 10E-4
Receiver noise power	-107 dBm
Interfering signal threshold	-113 dBm
Waveform	610K0F7W, 576kbps FSK

AN/SRC-57. The ship-based AN/SRC-57 uses an omnidirectional antenna to communicate with other ships and shore-based radios. The AN/SRC-57 can tune over the 1350-1850 MHz frequency band for operations in international waters. However, operations close to the continental US (CONUS) restrict the frequencies of operations to 1350-1390 MHz, 1432-1435 MHz, and 1710-1850 MHz. The AN/SRC-57 can experience shipboard interference interactions that could eliminate additional frequency bands. The AN/SRC-57 can receive interference from shipboard systems such as the TAS MK 23 radar, AN/SPS-49 radar, and INMARSAT and can cause interference to GPS, INMARSAT, and AN/SMQ-11 Weather Satellite Receivers.

The AN/SRC-57 requires a 50-MHz minimum frequency separation between the site transmitter and receiver for ship-to-ship duplex links; however, ship-to-shore links must conform to the 62 MHz separation requirements of the AN/MRC-142. The technical parameters of the AN/SRC-57 used in the assessment are presented in Table D-4.

Table D-4. AN/SRC-57 Parameters (J/F 12/7652)

Frequency range	1350 – 1850 MHz
Transmit power	5 – 250 W
Emission Bandwidth (MHz)	1.0 (-3dB), 3.0 (-20 dB), 8.0 (-60 dB)
Antenna gain	1.5 dBi Omni
Antenna height	30 m
Receiver bandwidth (MHz)	1.6 (-3 dB), 4.0 (-20 dB), 9.2 (-60 dB)
Receiver noise figure	7 dB
Receiver sensitivity	-84 dBm BER = 10E-5
Receiver noise power	-105 dBm
Interfering signal threshold	-111 dBm
Waveform	2M85F7D, 144-2304 Kb/s binary FSK

D.3 ASSESSMENT

The technical parameters for the tactical radios (see the *System Description* section) were obtained from the Spectrum Certification Applications and from data provided by the program manager for each radio. The technical parameters for the IMT-2000 radios used in the sharing assessment are presented in a previous section of this report. The interference threshold values of the IMT-2000 CDMA system receivers are referenced to the data rate of the CDMA modulation. The interference threshold referenced to the receiver bandwidth would be increased by the ratio of the receiver bandwidth to the data rate. The revised interference thresholds (I_t) are presented in Table D-5.

Table D-5. CDMA-2000 Receiver Interference Thresholds

	CDMA-2000 NB (1.25 MHz)		CDMA-2000 WB (3.75 MHz)	
	Base	Mobile	Base	Mobile
Interference Threshold 1	-114.6 dBm	-110.6 dBm	-109.9 dBm	-105.9 dBm
Interference Threshold 2	-99.1 dBm	-95.1 dBm	-94.4 dBm	-90.4 dBm

The interference thresholds for the DoD tactical radio receivers were based on the Recommendation ITU-R F.1334, which limits the degradation due to interference in the fixed service receiver to 1 dB. This value corresponds to an allowed interference-to-noise power ratio (I/N) of –6 dB. Also, for one example, an additional, higher threshold was used, assuming a desired signal level of –75 dBm, and an S/(I+N) of 14 dB.

The analysis was performed to identify the required distance separation to protect the tactical radio relay receivers from the IMT-2000 transmitters and the IMT-2000 receivers from the tactical radio relay transmitters. The required propagation loss was calculated using transmitter powers, transmitter and receiver antenna gains, frequency-dependent rejection, and the receiver interference threshold as follows:

$$L_P = P_T + G_T + G_R + L_S - FDR - I_T \tag{D-1}$$

where:

L_P = required propagation path loss to preclude interference (dB)
P_T = output power of the source transmitter (dBm)
G_T = source transmit antenna gain in the direction of the victim receiver (dBi)
G_R = victim receive antenna gain in the direction of the source transmitter (dBi)
L_S = transmitter and receiver line losses (dB)
FDR = frequency-dependent rejection (dB)
I_T = receiver interference threshold (dBm).

The Spherical Earth Model (SEM) was used to determine the required distance separation to preclude interference. The SEM is applicable to paths over a smooth, spherical, homogenous, and imperfectly-conducting earth. The dominant mode of propagation can be either LOS, diffraction, or tropospheric forward-scatter. The SEM calculates the required distance separation based on the required propagation loss, link frequency, and transmitter/receiver antenna heights.

The above assessment was used to evaluate the frequency separation versus distance separation requirements for one sample case of the AN/GRC-226 and the CDMA WB (3.75 MHz). The receiver selectivity and the transmitter emission spectrum were off-tuned, and the FDR was determined for several values of frequency separation.

D.4 RESULTS

The IMT-2000 to tactical radio relay distance separation requirements are presented in Table D-6, the tactical radio relay to IMT-2000 (minimum interference threshold) distance requirements are presented in Table D-7, and the tactical radio relay to IMT-2000 (more typical interference threshold) distance separation requirements are presented in Table D-8.

Table D-6. IMT-2000 to Tactical Radio Relay Distance Separation Requirements Co-Channel Operation

Interference Path		CDMA NB	CDMA WB	IS-136	GSM
Source	Victim	Distance (Km)	Distance (Km)	Distance (Km)	Distance (Km)
IMT-2000 Base	**GRC-226 MB**	87.1	78.1	91.9	91.1
IMT-2000 Base	**GRC-226 SL**	63.9	60.7	65.5	65.2
IMT-2000 Base SL	**GRC-226 SL**	52.3	49.0	53.9	53.7
IMT-2000 Mobile	**GRC-226 MB**	22.5	19.8	23.8	23.6
IMT-2000 Mobile	**GRC-226 SL**	11	9.2	11.9	11.8
IMT-2000 Base	**GRC-245 MB**	75.2	74.7	75.5	75.5
IMT-2000 Base	**GRC-245 SL**	56.8	56.5	57.0	57.0
IMT-2000 Base SL	**GRC-245 SL**	45.0	44.6	45.1	45.1
IMT-2000 Mobile	**GRC-245 MB**	18.8	18.5	19.0	19
IMT-2000 Mobile	**GRC-245 SL**	7.4	7.2	7.5	7.5
IMT-2000 Base	**MRC-142 MB**	85.5	75.7	91.9	91.1
IMT-2000 Base	**MRC-142 SL**	63.4	59.8	65.5	65.2
IMT-2000 Base SL	**MRC-142 SL**	51.8	48.0	53.9	53.7
IMT-2000 Mobile	**MRC-142 MB**	22.0	19.0	23.8	23.6
IMT-2000 Mobile	**MRC-142 SL**	10.7	8.7	11.9	11.8
IMT-2000 Base	**SRC-57**	62.0	59.0	63.3	63.1
IMT-2000 Base SL	**SRC-57**	50.3	47.2	51.7	51.5
IMT-2000 Mobile	**SRC-57**	10	8.4	10.6	10.5

Table D-7. Tactical Radio Relay to IMT-2000 Distance Separation Requirements
Co-Channel Operation

Minimum Interference Threshold

Interference Path		**CDMA NB**	**CDMA WB**	**IS-136**	**GSM**
Source	**Victim***	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**
GRC-226 MB	**IMT-2000 Base**	82	75.4	85.0	84.2
GRC-226 SL	**IMT-2000 Base**	62.2	59.6	63.2	62.9
GRC-226 SL	**IMT-2000 Base SL**	50.5	47.9	51.6	51.3
GRC-226 MB	**IMT-2000 Mobile**	34	31.5	35.0	34.7
GRC-226 SL	**IMT-2000 Mobile**	19.5	17.5	20.4	20.2
GRC-245 MB	**IMT-2000 Base**	73.7	71.9	75.2	74.1
GRC-245 SL	**IMT-2000 Base**	55.4	53.5	56.1	55.9
GRC-245 SL	**IMT-2000 Base SL**	43.5	41.6	44.3	44.1
GRC-245 MB	**IMT-2000 Mobile**	30.0	28.3	30.7	30.5
GRC-245 SL	**IMT-2000 Mobile**	14.5	13.3	15.0	14.9
MRC-142 MB	**IMT-2000 Base**	81.3	73.6	91.4	90.5
MRC-142 SL	**IMT-2000 Base**	61.9	58	65.6	65
MRC-142 SL	**IMT-2000 Base SL**	50.2	46.2	54.1	53.5
MRC-142 MB	**IMT-2000 Mobile**	33.7	29.9	37.4	36.8
MRC-142 SL	**IMT-2000 Mobile**	19.4	16.3	22.5	21.9
SRC-57 HP	**IMT-2000 Base**	79.8	74.0	83.5	82.7
SRC-57 LP	**IMT-2000 Base**	62.2	59.3	63.6	63.3
SRC-57 HP	**IMT-2000 Base SL**	65.7	62.9	67.0	66.8
SRC-57 LP	**IMT-2000 Base SL**	50.6	47.6	52.0	51.7
SRC-57 HP	**IMT-2000 Mobile**	33.2	30.3	34.5	34.2
SRC-57 LP	**IMT-2000 Mobile**	19.6	17.3	20.7	20.5

*Desired signal at sensitivity, I/N = - 6 dB

Table D-8. Tactical Radio Relay to IMT-2000 Distance Separation Requirements Co-Channel Operation

Typical Interference Threshold

Interference Path		CDMA NB	CDMA WB	IS-136	GSM
Source	**Victim***	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**	**Distance (Km)**
GRC-226 MB	**IMT-2000 Base**	64.3	61.8	65.4	65.1
GRC-226 SL	**IMT-2000 Base**	48.2	45.6	49.3	49.0
GRC-226 SL	**IMT-2000 Base SL**	36.2	33.6	37.4	37.1
GRC-226 MB	**IMT-2000 Mobile**	21.3	19.2	22.2	22.0
GRC-226 SL	**IMT-2000 Mobile**	10.2	8.9	10.8	10.7
GRC-245 MB	**IMT-2000 Base**	60.3	58.4	61.0	60.8
GRC-245 SL	**IMT-2000 Base**	41.2	39.3	42.0	41.8
GRC-245 SL	**IMT-2000 Base SL**	29.3	27.4	30.0	29.8
GRC-245 MB	**IMT-2000 Mobile**	18.1	16.7	18.6	18.5
GRC-245 SL	**IMT-2000 Mobile**	7.0	6.2	7.3	7.2
MRC-142 MB	**IMT-2000 Base**	64.1	60.2	67.8	67.2
MRC-142 SL	**IMT-2000 Base**	47.9	43.9	51.8	51.2
MRC-142 SL	**IMT-2000 Base SL**	36.0	31.9	39.9	39.3
MRC-142 MB	**IMT-2000 Mobile**	21.1	18.0	24.4	23.8
MRC-142 SL	**IMT-2000 Mobile**	10.1	8.1	12.3	11.9
SRC-57 HP	**IMT-2000 Base**	63.6	60.7	64.9	64.6
SRC-57 LP	**IMT-2000 Base**	48.3	45.3	49.7	49.4
SRC-57 HP	**IMT-2000 Base SL**	52.0	48.9	53.3	53.0
SRC-57 LP	**IMT-2000 Base SL**	36.3	33.3	37.7	37.5
SRC-57 HP	**IMT-2000 Mobile**	20.7	18.3	21.8	21.6
SRC-57 LP	**IMT-2000 Mobile**	10.3	8.7	11.0	10.9

*Desired Signal 10 dB above sensitivity and BER = 10E-3

For the minimum interference threshold case, the distance separation requirements between the tactical radio relay and the IMT-2000 base stations would be approximately 92 km if random antenna orientations were allowed for both systems. With the same interference threshold, the distance separation requirements between the tactical radio relay and the IMT-2000 base stations would be approximately 55 km if side-lobe antenna orientations were constrained for each system toward the other system (assumes low-power operation for the AN/SRC-57).

With the minimum interference threshold, the distance separation requirements between the tactical radio relay and the IMT-2000 mobiles would be approximately 38 km if random antenna orientations were allowed for the tactical radio relay. If tactical radio relay main-beam antenna orientations (assumes low-power operation for the AN/SRC-57) were constrained away from areas of IMT-2000 operations and IMT-2000 mobiles were restricted from some areas of operations, the distance separation requirements would be approximately 23 km. The above distance separation requirements cannot be accommodated in many areas of tactical radio relay operations in the US.

For one example interaction, the distance separation requirements were also determined for the case of a tactical radio relay link with a typical received signal level. The example uses CDMA WB (3.75 MHz) interference to an AN/GRC-226 receiver. The AN/GRC-226 link with an elevated site location and favorable weather parameters could receive a faded desired signal level of -75 dBm with a corresponding interference threshold of -89 dBm, for an S/(I+N) = 14 dB. The required distance separation values for this example are presented in Table D-9.

If a an interference threshold for a typical received signal level (approximately 10 dB above receiver sensitivity for the IMT-2000 or -75 dBm for the AN/GRC-226) is used, the separation requirements are 68 km and 40 km for random antenna orientations (main-beam) and side-lobe antenna orientations, respectively. These less conservative separation distances would still be difficult implement at most tactical radio relay operations areas.

The frequency separation verses distance separation requirements for one sample case of the AN/GRC-226 and the CDMA WB (3.75 MHz) are presented in Table D-10. The frequency separation was limited to 5 MHz because data was not available on the IMT-2000 systems that are under development. These preliminary calculations indicate that separation distances of 34.5 km are required for one channel separation (5MHz) between the AN/GRC-226 and the CDMA WB (3.75 MHz) base station.

Table D-9. CDMA-2000 NB (1.25 MHz) to AN/GRC-226
Co-Channel Operation

Interference Path		Source Transmitter Data			Victim Receiver Data			FDR	Path Loss	Distance
Source	Victim	Power dBm	Antenna dBi	TX Cable dB	Int Thresh dBm	Antenna dBi	RX Cable dB	dB	dB	SEM Km
CDMA NB Base	GRC-226 MB	40	15	1	-89	20	2.4	1.8	158.8	58.6
CDMA NB Base	GRC-226 SL	40	15	1	-89	2	2.4	1.8	140.8	42.2
CDMA NB Base SL	GRC-226 SL	40	2	1	-89	2	2.4	1.8	127.8	30.3
CDMA NB Mobile	GRC-226 MB	20	0	0	-89	20	2.4	1.8	124.8	8.2
CDMA NB Mobile	GRC-226 SL	20	0	0	-89	2	2.4	1.8	106.8	3.0

Table D-10. Frequency Verses Distance Separation Requirements for the AN/GRC-226 and the CDMA-2000 WB (3.75 MHz)

Interference Path		Off-tuning	Separation Distance
Source	Victim	MHz	Km
GRC-226 MB	CDMA WB Base	0	75.3
		1.0	75.3
		2.0	70.6
		3.0	58.3
		4.0	45.6
		5.0	34.5
CDMA WB Base	GRC-226 MB	0	78.1
		1.0	75.3
		2.0	69.9
		3.0	55.7
		4.0	20.5
		5.0	16.4

D.5 CONCLUSIONS

The full band sharing of the 1755-1850 MHz frequency band by the IMT-2000 and transportable tactical radio relay does not appear feasible based on the current projections of the IMT-2000 configuration. The IMT-2000 base station to tactical radio relay distance separation requirements (based on I/N = -6 dB) of 92 km (main-beam to main-beam) to 55 km (side-lobe to side-lobe) cannot be satisfied at many locations with tactical radio relay operations. Even if a less conservative interference threshold is used (sensitivity +10 dB for the IMT-2000 and -75 dBm for the AN/GRC-226), the IMT-2000 and tactical radio relay receivers still require 68 km and 40 km of separation.

D.6 MITIGATION TECHNIQUES

There are several mitigation techniques which should be explored to reduce the distance separation requirements and allow band sharing as follows:

- Investigate segmenting the 1755-1850 MHz frequency band; however, segementation of the 1755-1850 MHz frequency band may result in spectrum spillover into adjacent bands.
- Identify cross-polarization between IMT-2000 base stations and the tactical radio relay can reduce the level of interference interactions.

APPENDIX E – POTENTIAL FOR INTERFERENCE BETWEEN IMT-2000 ENVIRONMENT AND AIR COMBAT TRAINING SYSTEMS (1755-1850 MHZ)

The 1755-1850 MHz frequency band is used by Air Combat Training Systems (ACTS) such as the Air Force's Air Combat Maneuvering Instrumentation (ACMI) and the identical Navy Tactical Aircrew Combat Training System (TACTS). These existing ACTS systems transmit data to the aircraft on either 1830 or 1840 MHz and receive data from the aircraft on either 1778 MHz or 1788 MHz. Ranging tones and 198.4 kbps data, using frequency shift keying, are transmitted. Point-to-point links in this band are also used to communicate the data from remote sites to a central location.

In the future, the Joint Tactical Combat Training System (JTCTS) is scheduled to replace the existing ACTS. The JTCTS data links also operate air-to-ground, ground-to-air, and ground-to-ground, and can tune across the band 1710-1850 MHz in 5 MHz increments. The JTCTS data link signal structure is l6-ary, orthogonal signaling, with 0.351, 0.703, and 1.406 kbps data rates combined with either 5.63 or 22.5 Mchips/s pseudorandom spreading codes.

This appendix addresses the possible interference between IMT-2000 base and mobile stations and the ACTS, also described as the TACTS/ACMI and the JTCTS operating in the frequency band 1755-1850 MHz.

E.1 SYSTEM DESCRIPTIONS

Technical characteristics of the TACTS/ACMI and JTCTS, together with relevant operational assumptions, are given in the following paragraphs.

E.1.1 TACTS/ACMI Characteristics

E.1.1.1 System Characteristics

Characteristics of the TACTS/ACMI system are given in Tables E-1, E-2, and E-3. Values are those in the frequency allocation applications,[1,2,3,4] unless noted otherwise. Certain parameters of the internal

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[1] Application for Equipment Frequency Allocation (DD Form 1494) for AN/TSQ-T4 Master Station and subsequent Notes to Holders, J/F 12/4321, Washington, DC: MCEB, April 1975.

AIS units were not available. The values were estimated based on the corresponding parameters of the AIS pod units, and these parameters are indicated by the shaded cells of Tables E-1 and E-2. For transmitter emission bandwidths and receiver IF bandwidths, as well as harmonic and spurious levels, the DD Form 1494 values were used instead of the specified values.[5] It was felt the specified values represented a limit not to be exceeded, while the 1494 values more closely represented actual system characteristics. TACTS/ACMI frequencies and the link types associated with their use are listed in Table E-4.

E.1.1.2 Operational Considerations

In an earlier analysis for the Air Force Frequency Management Agency (AFFMA),[6] ground-to-air separation distances of 78 and 35 km were used. These values correspond to 48.5 mi (42.1 nmi) and 21.75 mi (18.9 nmi) respectively. The specified nominal maximum range appears to be 65 nmi.[7] The separation distances of 78 km (42.1 nmi) and 35 km (18.9 nmi) were used in the TACTS/ACMI portion of this analysis.

The maximum number of aircraft is stated to be 36 (Reference 7). In this analysis, the effect of the number of aircraft flying at a given time was not considered.

Altitudes of 5000 m (16,400 ft) and 9000 m (29,530 ft) were used in Reference 6. A somewhat higher maximum altitude of 40,000 feet above range floor is given in Reference 5, and altitudes of 55,000 to 60,000 feet are given for the internal AIS equipment.[8] The 9000 m (approximately 30,000 ft) altitude was used in this analysis.

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[2] Application for Equipment Frequency Allocation (DD Form 1494) for AN/TSQ-T4 Remote Stations and subsequent Notes to Holders, J/F 12/4322, Washington, DC: MCEB, April 1975.

[3] Application for Equipment Frequency Allocation (DD Form 1494) for AN/TSQ-T4 Up Link and subsequent Notes to Holders, J/F 12/4323, Washington, DC: MCEB, April 1975.

[4] Application for Equipment Frequency Allocation (DD Form 1494) for TACTS,ACMI AIS Pods and subsequent Notes to Holders, J/F 12/4324/2, Washington, DC: Naval Air Systems Command, May 1987.

[5] Fred Williar, Naval Air Systems Command, e-mail to Allan Baker, JSC/IITRI, Subject: More TACTS Data, Patuxent River NAS, MD, September 27, 2000.

[6] Wayne Wamback, The Potential for Interference Between IMT-2000 Systems and U.S. DoD Systems Operating in the Frequency Band 1755-1850 MHz, Annex 2, Alexandria, VA: AFFMA, 28 February 2000.

[7] James E. Keeler, AAC/WMRR, e-mail to J. Don Simmons, Civ AAC/WMRR, *Subject, DoD Forms for 1755 – 1850 MHz IMT-2000 Study*, September 13, 2000.

[8] Fred Williar, Naval Air Systems Command, e-mail to Allan Baker, JSC/IITRI, S*ubject: TACTS AIS Data,* Patuxent River NAS, MD, September 27, 2000.

Table E-1. TACTS/ACMI Transmitter Characteristics

Transmitter Characteris-tic	TIS Master	TIS Remote	TIS Uplink	AIS Downlink (Pod)[a]	AIS Downlink (Internal)[d]
Power (W)	20	1 or 5[b]	5 [c]	20	10-15 (min)[e]
Modulation Type	FSK,PM	FSK,PM	FSK,PM	FSK,PM	FSK,PM
Modulation Indices	0.9,0.3,0.3	0.9,0.3,0.3	9,3,3	9,3,3	8.2,2.7,2.7
Carrier Deviation (FSK)	± 74.4 kHz	± 74.4 kHz	± 74.4 kHz	± 74.4 kHz	± 74.4 kHz
Data Rate (kbps)	198	198	198	198	198
Widest Emission Bandwidth (MHz)					
-3 dB	0.6	0.6	3.0	2.0	3.0
-20 dB	0.8	0.8	7.0	8.0	7.0
-60 dB	2.1	2.1	12.0	12.0	12.0
Harmonic Attenuation (dB)	70	70	70	85	85
Spurious Attenuation (dB)	70	70	70	70	70

[a] The calibration transponder at the master station is electronically identical to the AIS pod.
[b] Depends on manufacturer. Cubic Corp. uses 1 W, ADT uses 5 W (Ref. 5).
[c] 20 W at Tyndall ACMI and Yukon MDS ranges (Ref. 5).
[d] Data consolidated from Ref. 8.
[e] 15 W applies to AISI(K) (Ref. 8).

Table E-2. TACTS/ACMI Receiver Characteristics

Receiver Characteris-tic	TIS Master	TIS Remote	TIS Downlink	AIS[a] (Pod)	AIS (Internal)[d]
Sensitivity (dBm)	-95 (BER = $1x10^{-5}$)	-95 (BER = $1x10^{-5}$)	-95 (BER = $1x10^{-5}$)	-99 (10 dB S/N) (BER = $1x10^{-5}$)	-95 dBm (100% response), -99 dBm (50% response)
Noise Level[e] (dBm)	-110	-110	-110	-111	-111
IF Bandwidth[b] (MHz)					
-3 dB	1.5	1.5	1.5	1.2	1.2
-20 dB	5.0	5.0	5.0	3.0	3.0
-60 dB	12.0	12.0	12.0	8.0	8.0
Receiver Selectivity[c] (MHz)					
-3 dB	1.5	1.5	1.5	1.2	1.2
-20 dB	2.9	2.9	2.9	3.0	3.0
-60 dB	7.4	7.4	7.4	6.8	6.8
Spurious Response (dB)	60	60	85	85	85

[a] The calibration transponder at the master station is electronically identical to the AIS pod.
[b] Second IF bandwidth
[c] Bandwidth of combined first and second IF stages.
[d] Data consolidated from Ref. 8.
[e] Calculated using 2.7 dB noise figure, from Ref. 5.

Table E-3. TACTS/ACMI Antenna Characteristics

Antenna Characteristic	TIS Master	TIS Remote	TIS Uplink/ Downlink	AIS (Pod)	AIS (Internal)
Type	Parabolic (Dipole Arrays)/ Broad Beamwidth	Parabolic	Crossed Dipole Array	Dipole	Dipole
Gain (dBi)	28,24, 20[d]/14.5	26	3.0	0	0
Polarization	V & H	V,H	RHCP	RHCP	RHCP
Height (ft)	75 (300 max)[e]	100-150	160 (100-150)[e]	30,000[a,c]	55,000-60,000[a,b]

[a]Maximum altitude above mean sea level
[b]From Reference 8.
[c]Reference 5 gives a range of 10,000 to 30,000 ft. This reference also states that the TIS is specified to track aircraft within altitudes of 500 ft. to 40,000 ft above the range floor.
[d]Different values are given. The 20 dB value is given in Reference 1. Although a broad beamwidth is usually desired, the antenna gain may depend on the installation.
[e]Antenna height is site-dependent.

Table E-4. TACTS/ACMI Frequencies and Usage

Type of Link	Frequencies (MHz)
Master-to-Remote	1768 or 1769
AIS-to-Remote (Downlink)	1788 “A” Pod or 1778 “B” Pod
Remote-to-Master	1797, 1802, 1807, 1812, 1817, 1822
Remote-to-AIS (Uplink)	1840 “A” Pod or 1830 “B” Pod

E.1.2 JTCTS Characteristics

E.1.2.1 System Characteristics

Tables E-5, E-6, and E-7 contain characteristics of the JTCTS. Characteristics were obtained from the frequency allocation application,[9] SRI International reports[10,11] and material from the system

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[9] Application for Equipment Frequency Allocation (DD Form 1494) for Joint Tactical Combat Training System (JTCTS) Instrumentation Data Network, (Stage 4), J/F 12/06999/2, Patuxent River, MD, NAWCAD, 10 July 1998.

[10] David Hanz, Results from Phase 1a of the GSM-1800/JTCTS Datalink Signal Compatibility Test Program, Special Report 10240-99-SR-110, Menlo Park, CA: SRI International, November 1999.

[11] US DoD Air Combat Training Systems Development Roadmap for Next Generation & Spectrum Compatibility Issues, dated 12 January 2000. Briefing given by D. Hanz of SRI International, 11 September 2000.

manufacturer which was provided by SRI International[12,13] The high-power mode of operation (67.6 W) was assumed. The shaded boxes contain assumed values.

E.1.2.1.2 Operational Considerations

In Reference 6, ground-to-air separation distances of 78 and 35 km were used for both the TACTS/ACMI and JTCTS analyses. These values correspond to 48.5 mi (42.1 nmi) and 21.75 mi (18.9 nmi) respectively. However, it is realized that for the JTCTS, the ground-to-air links are secondary and tertiary links. The primary link is the air-to-air link, with a maximum distance of 150 nmi (278 km). A separation distance of this magnitude plus a smaller one (78 km or approximately 50 mi) were used in the analysis.

The maximum number of aircraft is stated to be 100 for JTCTS, according to discussions at a 25 September 2000 meeting with NAVAIR and SRI International personnel and to Reference 7. Typical numbers of aircraft may be somewhat less. In this analysis, the effect of the number of aircraft flying at a particular time was not considered.

Altitudes of 5000 m (16,400 ft) and 9000 m (29,530 ft) were used in Reference 6. Some of the material provided for the TACTS system indicates that maximum altitudes may be higher (e.g., 40,000 to 60,000 feet). However, after coordination with JTCTS engineering and operational personnel, an altitude of 9000 m (approximately 30,000 ft) was used in both the TACTS and JTCTS parts of the analysis.

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[12] Raytheon Systems Company, *JTCTS Data Link Overview*, Slide Package, undated, attachment to D. Hanz, SRI International, e-mail to A. Baker, IITRI/JSC, September 25, 2000. *Subject: Reference Material #1.*

[13] Dave Hanz, SRI International, e-mail to Allan Baker, IITRI/JSC, Subject: More Reference, 25 September 2000, with attachment Raytheon Specification G644379 8 February 1996 CAGE Code 49956 Rev. A: 31 December 1996.

Table E-5. JTCTS Transmitter Characteristics

Transmitter Characteristic	Narrowband	Wideband
Power (W)	7.6 or 67.6	7.6 or 67.6
Tuning	Frequencies are selectable from 1710-1850 MHz in 5-MHz increments (1755-1850 MHz in US & P).	
Modulation Type	OQPSK with DS spread spectrum, 16-ary orthogonal Walsh signaling	
Data Rate (kbps)	351.5625, 703.125, 1406.25	351.5625, 703.125, 1406.25
Chip Rate (Mcps)	5.63	22.5
Protocol	TDMA-100 ms frame, Primary IDN: 25 slots/frame Secondary IDN: 10 slots/frame	
Error Detection and Correction	Reed-Solomon FEC Short Data Slots: (116,100) Long Data Slots: (128,100) Relay Slots: (56,40)	
Emission Bandwidth (MHz)		
-3 dB	2.1	4.8
-20 dB	5.63	22.5
-60 dB	22.5	90
Harmonic Attenuation (dB)		
(2 & 3)	70	70
Other	80	80
Spurious Attenuation (dB)	80	80

Table E-6. JTCTS Receiver Characteristics

Receiver Characteristic		
Sensitivity (dBm)	-106.5 @ 14.1 dB E_b/N_o, 351.56 kb/s, RS coding	
Noise Figure (dB)	4.5	
Receiver Noise Level, dBm[b]	-114.0 (352.6 kbps), -111.0 (703 kbps), -108 dBm (1406 kbps)	
First IF Bandwidth (MHz)	Narrowband[c]	Wideband
-3 dB	22.5	22.5
-20 dB	45	45
-60 dB	60	60
Implementation Losses (dB)	2	
Spurious Response (dB)	60	
Image Rejection (dB)	100	
Intermediate Frequency (MHz)	400	

[a] It is expected that additional selectivity is present, at the second IF or baseband

[b] In bandwidth equal to the bit rate.

[c] No additional filtering is used for the narrowband mode.[14]

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[14] David Hanz, SRI International, e-mail to Allan Baker, IITRI/JSC, 9 October 2000, Subject: JTCTS Characteristics.

Table E-7. JTCTS Antenna Characteristics

Antenna Characteristic	Instrumentation Data Link (Aircraft Fuselage Mounted)	Instrumentation Data Link (Aircraft Pod Mounted)	Ship-to-Shore Link
Type	¼ λ monopole blade	½ λ crossed dipoles	Stacked dipole array
Gain (dBi)	2	6	8
Polarization	V	H,V	V
Height (ft)	30,000	30,000	

E.2 POTENTIAL FOR INTERFERENCE FROM IMT-2000 INTO TACTS/ACMI

E.2.1 Interference from IMT-2000 into TACTS/ACMI Airborne Receivers

The calculation of aggregate IMT-2000 interference into the TACTS/ACMI and JTCTS airborne receivers was done in a manner similar to that in Reference 6, which was based on the levels used in Recommendation ITU-R M.687-2.[15] Two training ranges were selected, Cherry Point MCAS, in the eastern US, and Nellis AFB in the western US. Both training ranges were within LOS of at least one major metropolitan area. For each training range, a point within the boundary of the flight area was selected, and metropolitan areas within the radio LOS of this point were selected. The assumed aircraft receiver altitude was 9000 m (approximately 30,000 ft), and the radio LOS was calculated to be approximately 260 miles. For each city, the equivalent area was calculated, and the propagation loss was calculated using the JSC Smooth Earth Model (SEM)[16] with the modified free space option. Antenna heights used were 40 m for the IMT-2000 base stations and 9000 m for the airborne receiver.

The total power at the airborne receiver was calculated using Equation E-1 (Adapted from Reference 6):

$$I(\text{dBW/Hz}) = \sum_{i=1}^{n} P_d \, P_{mi} \, D_{pl} \, l_{pi} \qquad \text{(E-1)}$$

where:

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[15] International Telecommunications Union, International Mobile Telecommunications-2000 (IMT-2000), Recommendation ITU-R M.687-2, 1997.

[16] David Eppink and Wolf Kuebler, *TIREM/SEM Handbook*, ECAC-HDBK-93-076, Annapolis, MD: DoD ECAC, March 1994.

P_d = power density per square kilometer per Hertz generated by IMT-2000 stations in an urban environment. Given by Reference 15 as 38 $\mu W/km^2/Hz$

P_{mi} = population of the ith visible metropolitan area, in millions

D_{pl} = average inverse population density, in km^2 per million

l_{pi} = path loss from the ith metropolitan area, equal to $10^{-L/10}$, where L is the path loss from the JSC Smooth Earth Model (SEM), in dB

Values of P_m used were the populations of the Ranally Metropolitan Areas, taken from the Rand McNally Commercial Atlas and Marketing Guide.[17] The values used are population estimates for 1 January 1999.

In Reference 6, the average population density was determined by averaging the population densities of the metropolitan areas or central cities for eight world cities. The average ratio was calculated to be 144.2 km^2/million.

As in Reference 6, a factor for environmental losses, 10 dB, was subtracted from the results of Equation E-1. Use of a lesser value, such as 0 dB, was also considered.

The results of the calculations using Equation E-1 are given in Tables E-8 and E-9 for Nellis AFB and Cherry Point, respectively.

Table E-8. Power Levels from Nearby Cities, Nellis AFB ACMI Range

City	Distance		Population (Metro Area) (mil.)	Equiv. Area (km^2)	Path Loss, dB	Received Power Density (dBW/Hz)
	Miles	km				
Las Vegas, NV	58	93	1.2575	181.3	137	-158.6
Los Angeles, CA	260	418.4	13.11	1890.5	169.7	-181.1
Bakersfield, CA	234	376.6	0.404	58.24	149.1	-175.6
Fresno, CA	253	407.1	0.726	104.7	159.7	-183.7
Riverside, CA	234	376.6	1.536	221.5	149.1	-169.8

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[17] Rand McNally & Co., Rand McNally 2000 Commercial Atlas & Marketing Guide, 131st Edition, 2000, pp. 124-125.

The total power density is -158.2 dBW/Hz; with a 10 dB factor for environmental losses, it is -168.2 dBW/Hz.

Table E-9. Power Levels from Nearby Cities, Cherry Point MCAS

City	Distance		Population (Metro Area) (mil.)	Equiv. Area (km^2)	Path Loss, dB	Received Power Density (dBW/Hz)
	Miles	km				
Richmond VA	200	322	.861	124.1	147.7	-171.0
Norfolk, VA	140	225	1.006	144.9	144.6	-167.2
Newport News, VA	140	225	0.476	68.6	144.6	-170.4
Fayette-ville, NC	135	217	0.319	46.1	144.3	-171.9
Charlotte, NC	240	386	1.215	175.3	149.3	-171.1
Charleston, SC	240	386	0.4782	69.1	149.3	-175.1
Columbia, SC	260	418	0.4924	71.0	169.4	-195.1
Raleigh, NC	140	225	0.6733	97.1	144.6	-168.9
Durham, NC	140	225	0.3273	47.2	144.6	-172.1

The total power was calculated to be -161.4 dBW/Hz; with a 10 dB factor for environmental losses, it is -171.4 dBW/Hz.

Results of the interference calculations are given in Table E-10 for TACTS/ACMI air-to-ground separation distances of 35 and 78 km, for the aggregate interfering signal without environmental losses, the interfering signal with 10 dB losses, and the interfering signal attenuated by 10 dB, with the 10 dB loss factor. The 10 dB attenuation may approximate a situation where the IMT-2000 system is near the beginning of its full-scale implementation.

The results in Table E-10 show that the TACTS link margins are degraded to -22 to -29 dB, with the full aggregate interfering signal, with 10 dB of environmental losses. With 10 dB less interfering power than predicted with the full operational implementation, link margins are still degraded to -12 dB at the 35 km TACTS transmitter-to-receiver separation distance and -19 dB at the 78-km separation distance. Since a number of factors could cause the calculated numbers to be higher than those shown, the results suggest that sharing in a full IMT-2000 environment is not feasible.

Table E-10. TACTS/ACMI Airborne Receiver Link Margins With and Without IMT-2000 Interference

Aircraft Altitude	9000 m	9000 m
Distance from Ground Transmitter	78 km	35 km
Range Between A/C and Ground Transmitter	78.52 km	36.14 km
Ground Transmitter Power	7 dBW	7 dBW
Transmit Antenna Gain	0 dBi	0 dBi
Transmitter System Losses	2 dB	2 dB
Transmitter Data Rate (198.4 kbps)	53.0 dBHz	53.0 dBHz
Transmit E_b	-48 dBW	-48 dBW
Free Space Path Loss (1800 MHz)	135.4 dB	128.7 dB
Airborne Receiver Antenna Gain	0 dBi	0 dBi
Rx Noise (3 dB NF)	-201 dBW/Hz	-201 dBW/Hz
E_b/N_o	17.6 dB	24.3 dB
Criterion (E_b/N_o for BER = 10^{-5})	13.35 dB	13.35 dB
Margin (No Interference)	4.2 dB	10.9 dB
I_o	-158 dBW/Hz	-158 dBW/Hz
$E_b/(N_o + I_o)$	-25.4 dB	-18.7 dB
Degraded Below Criterion	38.8 dB	32.1 dB
I_o	-168 dBW/Hz	-168 dBW/Hz
$E_b/(N_o + I_o)$	-15.4 dB	-8.7 dB
Degraded Below Criterion	28.8 dB	22.1 dB
I_o	-178 dBW/Hz	-178 dBW/Hz
$E_b/(N_o + I_o)$	-5.4 dB	1.3 dB
Degraded Below Criterion	18.8 dB	12.1 dB
I_o	-188 dBW/Hz	-188 dBW/Hz
$E_b/(N_o + I_o)$	4.6 dB	11.3
Degraded Below Criterion	8.8 dB	2.1 dB

E.2.2 Interference from IMT-2000 into TACTS/ACMI Ground-Based Receivers

To analyze interference from IMT-2000 into TACTS/ACMI ground-based receivers, the required separation distance to preclude interference into a ground receiver from a single IMT-2000 base and mobile transmitter was calculated. The IMT-2000 parameters used in the calculations are given in Tables A-4 and A-5. The TACTS ground receiver and antenna parameters are given in Tables E-1, E-2, and E-3.

As was assumed in Reference 6, TACTS/ACMI operations are link-margin limited. The volume of space usable for flight training is determined by the available link margin. It was assumed that the maximum range between ground-based and airborne equipment, which determines the maximum aircraft-to-aircraft separation, cannot be reduced by more than ten percent due to interference from IMT-2000 systems. This condition equates to an allowed degradation in the TACTS/ACMI link margin of approximately 1 dB and an I/N of –6 dB. It is noted, as in Reference 6, that the full amount of interference degradation is made available to IMT-2000, rather than only ten percent of the total interference budget, as is often considered reasonable.

Interference between ground-based transmitters and receivers was calculated using Equation E-2:

$$I = P_T + G_T + G_R - L_P - L_S - L_{SP} - FDR \qquad \text{(E-2)}$$

where

I = interference power in receiver, in dBm
P_T = transmitter power, in dBm
G_T = transmitter antenna gain in direction of receiver, in dBi
G_R = receiver antenna gain in direction of transmitter, in dBi
L_P = propagation loss, in dB
L_S = system losses, in dB
L_{SP} = processing loss of interference in a spread spectrum receiver, in dB
FDR = frequency-dependent rejection, in dB.

The interference power I was set to a maximum allowable value, the interference threshold I_t, which is set for the TACTS/ACMI receivers at 6 dB below the receiver noise level, and Equation E-2 was rearranged to form Equation E-3:

$$L_P = P_T + G_T + G_R - L_S - L_{SP} - FDR - I_t \qquad \text{(E-3)}$$

where quantities are as previously defined.

The factor L_{SP}, for a direct-sequence spread spectrum receiver such as those used for CDMA versions of the IMT-2000, is given by Equation E-4:

$$L_{SP} = 10 \log (R_c/R_d) \qquad \text{(E-4)}$$

where:

R_c = chip rate of receiver, chips/s
R_d = data rate of system, bits/s.

Frequency dependent rejection (FDR) for the ontune cases considered here is given by Equation E-5:

$$\begin{aligned} FDR &= 10 \log (B_t/B_r) \quad \text{for } B_t > B_r \\ &0 \quad \text{for } B_t \leq B_r \end{aligned} \qquad \text{(E-5)}$$

where:

B_t = transmitter 3-dB emission bandwidth, in Hertz
B_r = receiver bandwidth, in Hertz.

The receiver bandwidth for use in Equation E-5 was assumed equal to the chip rate, for CDMA IMT-2000 receivers and other direct-sequence spread-spectrum receivers. For TDMA receivers, the receiver bandwidth and bit rate were assumed equal for this analysis, at 30 kHz for the IS-136 and 176 kHz for the GSM system, and the L_{SP} term is not applicable.

The required separation distance to preclude interference was calculated using the required propagation loss from Equation E-3 and the JSC Inverse Smooth Earth Model. Antenna heights used were 40 m and 1.5 m for the IMT-2000 base station and mobile transmitters respectively, and 30 m for the TACTS/ACMI receivers. The required separation distances are given in Table E-11. The distances shown are the maximum for all versions of the IMT-2000 listed in Tables A-4 and A-5. For one case, the wideband CDMA, a FDR of 3 dB would lower the separation distances slightly. For the other three IMT-2000 versions, the FDR is 0 dB. TACTS/ACMI antenna gain values of 26 dBi and 0 dBi were used. The 26 dBi gain represents either the master or the remote station in a ground-to-ground interaction. The 0 dBi gain represents the remote station used as a TIS uplink. It is expected that the 3 dBi gain shown in Table E-3 would be reduced by 3 dB for polarization differences between the right-hand circular polarization of the TACTS/ACMI antenna and the linear polarization of the interfering signal.

Table E-11. Distances, in km, from IMT-2000 Transmitters to Preclude Interference to TACTS/ACMI Ground-Based Receivers

TACTS/ACMI Antenna Gain (dBi)	IMT-2000 Station	
	Mobile	Base
0	20.0	70.1
26	38.9	146.1

E.3 INTERFERENCE FROM TACTS/ACMI INTO IMT-2000 SYSTEMS

E.3.1 Interference from TACTS/ACMI Ground-Based Transmitters into IMT-2000 System

Separation distances to be maintained by IMT-2000 receivers from TACTS/ACMI ground transmitters to preclude interference were calculated using the path loss from Equation E-3 and the inverse SEM propagation model. Parameters for the IMT-2000 receivers are taken from Tables A-4 and A-5 and parameters for the TACTS/ACMI transmitters and antennas were taken from Tables E-1 and E-3. For the IMT-2000 receiver interference criteria, the two values in Tables A-4 and A-5 were used, plus an additional, higher value, corresponding to the desired signal 20 dB above the receiver sensitivity level. It was felt that the two higher thresholds used would represent a range of realistic received signal levels. Separation distances for each interference threshold and TACTS/ACMI transmitter-antenna combination are given in Table E-12. For the highest interference threshold, only one value, the worst-case, was calculated. Distances for the other IMT-2000 versions are expected to be slightly less, as was the case for the lower thresholds.

For the narrowband TACTS signals, the Master Station (MS) and TIS ground-to-ground links, the separation distances for the CDMA WB and NB IMT-2000 implementations are slightly smaller than for the TDMA implementation. This is because the CDMA implementations offer some processing loss to the narrowband TACTS signal, due to the correlation of the desired signal and subsequent narrowband filtering in the receiver. The separation distances for both TDMA implementations were practically identical.

Table E-12. Distances, in km, from TACTS/ACMI Ground-Based Transmitters to Preclude Interference to IMT-2000 Receivers

TACTS/ACMI Antenna Gain and Tx Power	IMT-2000 Station					
	Mobile			Base		
	CDMA WB	CDMA NB	TDMA	CDMA WB	CDMA NB	TDMA
IMT-2000 Interference Criterion I/N = -6 dB						
MS 26 dBi/20 W	46	48.4	50.7	132.1	157.9	180.3
TIS 26 dBi/1 W	38.5	41.3	43.2	85.1	98.4	110
G/A 0 dBi/5 W	25.2	25.9	26	63.2	63.9	64
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB						
MS 26 dBi/20 W	36.9	39.8	41.8	80	90.8	101
TIS 26 dBi/1 W	27.9	31.4	33.7	66	69.7	72.5
G/A 0 dBi/5 W	11.9	12.7	12.8	49.2	50.1	50.2
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB						
MS 26 dBi/20 W			35.3			74.6
TIS 26 dBi/1 W			26.0			64.3
G/A 0 dBi/5 W			5.7			39.1

E.3.2 Interference from TACTS/ACMI Airborne Transmitters into IMT-2000 System

The required separation distances between an airborne TACTS/ACMI transmitter (at 9000 m altitude) and IMT-2000 base and mobile stations were calculated in a manner similar to those for the ground-based ACTS transmitters. For each value of required path loss, the JSC inverse smooth-earth propagation model was used to calculate the required separation distance. For the IMT-2000 base stations, a 2.5-degree downtilt angle was assumed and a maximum antenna gain, at the horizon or above, of 5 dBi was used in the analysis. Results of the calculations are shown in Table E-13. Because of the relatively wide bandwidth of the AIS downlink signal, little processing gain is realized by the CDMA implementations, and the separation distances for the three versions are not significantly different. The required separation distances for the base stations approach LOS for the lowest interference threshold, and they are in the neighborhood of 180 km for the middle interference threshold. These distances could significantly reduce the area of IMT-2000 usage near TACTS/ACMI training ranges.

Table E-13. Required Separation Distances, in km, to Preclude Interference from TACTS/ACMI Airborne Transmitters into IMT-2000 Receivers

IMT-2000 Station					
Mobile			Base		
CDMA WB	CDMA NB	TDMA	CDMA WB	CDMA NB	TDMA
IMT-2000 Interference Criterion I/N = -6 dB					
318.9	320.1	322.7	404.4	405.4	405.5
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB					
57.1	63.5	64.3	162.8	180.6	182.7
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB					
14.7	16.9	17.1	47.8	53.2	53.9

E.4 POTENTIAL FOR INTERFERENCE FROM IMT-2000 INTO JTCTS

E.4.1 Interference from IMT-2000 into JTCTS Airborne Receivers

The JTCTS data link signal structure is 16-ary, orthogonal signaling, with 0.351, 0.703, and 1.406 Mbps data rates combined with either 5.63 or 22.5 Mchips/s pseudorandom spreading codes. Symbol rates are 89.9, 175.8, and 351.5 ksps. The required E_s/N_o, including Reed-Solomon forward error-correcting code gain, is 11.0 dB.

Table E-14 contains the calculations of the JTCTS link margins for the aircraft altitude of 9000 m (approximately 30,000 feet), and two separation distances, in the absence of interference. The first separation distance, 78 km, is the same as used in the TACTS analysis. The second distance, 150 nmi (277.8 km) represents the specified maximum separation distance for the JTCTS air-to-air link (Reference 12), which is its primary communications link. In the absence of interference, link margins vary, depending on the symbol rate, from 16 to 22 dB for the 78 km distance, and from 5 to 11 dB for the 278 km distance.

It was assumed that the JTCTS was subjected to the same aggregate IMT-2000 interference levels as those calculated earlier for the TACTS/ACMI systems. Table E-15 shows the received $Es/(N_o + I_o)$ and resulting link margins in the presence of the aggregate IMT-2000 RF environment. With I_o = -168 dBW/Hz, negative link margins of from –10 to –16 dB result, depending on the data rate, for the 78 km distance. For the 150 nmi (278 km) separation, the link margins are 11 dB less, from –21 to –27 dB. For a l0-dB lower aggregate interference level, expected to occur before a mature usage rate is developed, negative link margins exist for all but the lowest symbol rate (87.9 ksps) at the 78 km separation, and at all symbol rates at the 278 km separation.

Comparison of the results for the JTCTS and TACTS/ACMI systems show that the JTCTS link margins are somewhat higher in the presence of interference, than are those of the TACTS/ACMI. However, the effect is still such that, even with an incomplete buildup of the IMT-2000 environment, operation of the systems at typical training ranges will be degraded.

Table E-14. JTCTS Airborne Receiver Link Margins Without IMT-2000 Interference

Aircraft Altitude	9000 m	9000 m
Distance from Tx	78 km	277.8 km (150 nmi)
Transmitter Power	18.3 dBW	18.3 dBW
Transmit Antenna Gain	2 dBi	2 dBi
Tx System Losses	2 dB	2 dB
Transmit Symbol Rate		
87.9 ksps	49.5 dBHz	49.5 dBHz
175.8 ksps	52.5 dBHz	52.5 dBHz
351.6 ksps	55.5 dBHz	55.5 dBHz
Transmit Energy per Symbol		
87.9 ksps	-31.2 dBW	-31.2 dBW
175.8 ksps	-34.2 dBW	-34.2 dBW
351.6 ksps	-37.2 dBW	-37.2 dBW
Free Space Path Loss (1800 MHz)	135.4 dB	146.4 dB
Airborne Receiver Antenna Gain	2 dBi	2 dBi
Received E_s		
87.9 ksps	-164.6 dBW	-175.6 dBW
175.8 ksps	-167.6 dBW	-178.6 dBW
351.6 ksps	-170.6 dBW	-181.6 dBW
Rx N_o (4.5 dB NF)	-199.5 dBW/Hz	-199.5 dBW/Hz
E_s/N_o		
87.9 ksps	34.9	23.9
175.8 ksps	31.9	20.0
351.6 ksps	28.9	17.9
Implementation Losses	2.0 dB	2.0 dB
Required E_s/N_o	11.0 dB	11.0 dB
Margin		
87.9 ksps	21.9 dB	10.9 dB
175.8 ksps	18.9 dB	7.9 dB
351.6 ksps	15.9 dB	4.9 dB

Table E-15. JTCTS Airborne Receiver Link Margins and Degradation Due to IMT-2000

Aircraft Altitude	9000 m	9000 m
Distance from Transmitter	78 km	277.8 km
Received E_s/N_o		
87.9 ksps	-164.6 dB	-175.6 dB
175.8 ksps	-167.6 dB	-178.6 dB
351.6 ksps	-170.6 dB	-181.6 dB
I_o	-158 dBW/Hz	-158 dBW/Hz
$E_s/(N_o + I_o)$		
87.9 ksps	-6.6 dB	-17.6 dB
175.8 ksps	-9.6 dB	-20.6 dB
351.6 ksps	-12.6 dB	-23.6 dB
Margin		
87.9 ksps	-19.6 dB	-30.6 dB
175.8 ksps	-22.6 dB	-33.6 dB
351.6 ksps	-25.6 dB	-36.6 dB
I_o	-168 dBW/Hz	-168 dBW/Hz
$E_s/(N_o + I_o)$		
87.9 ksps	3.4 dB	-7.6 dB
175.8 ksps	0.4 dB	-10.6 dB
351.6 ksps	-2.6 dB	-13.6 dB
Margin		
87.9 ksps	-9.6 dB	-20.6 dB
175.8 ksps	-12.6 dB	-23.6 dB
351.6 ksps	-15.6 dB	-26.6 dB
I_o	-178 dBW/Hz	-178 dBW/Hz
$E_s/(N_o + I_o)$		
87.9 ksps	13.4 dB	2.4 dB
175.8 ksps	10.4 dB	-0.6 dB
351.6 ksps	7.4 dB	-3.6 dB
Margin		
87.9 ksps	0.4 dB	-10.6 dB
175.8 ksps	-2.6 dB	-13.6 dB
351.6 ksps	-5.6 dB	-16.6 dB
I_o	-188 dBW/Hz	-188 dBW/Hz
$E_s/(N_o + I_o)$		
87.9 ksps	23.4 dB	12.4 dB
175.8 ksps	20.4 dB	9.4 dB
351.6 ksps	17.4 dB	6.4 dB
Margin		
87.9 ksps	10.4 dB	-0.6dB
175.8 ksps	7.4 dB	-3.6 dB
351.6 ksps	4.4 dB	-6.6 dB

E.4.2 Interference from IMT-2000 into JTCTS Ground-Based Receivers

As was done for the TACTS/ACMI, it was assumed for the JTCTS that the maximum range between ground and air stations (which in turn determines the maximum aircraft-to-aircraft separation) cannot be reduced by more than about 10 percent due to interference from IMT-2000 systems. This condition equates to an allowed degradation in the JTCTS link margin of approximately 1 dB and an interference-to-noise power ratio criterion of –6 dB. It again is noted that the full amount of interference degradation is made available to IMT-2000, rather than apportioning only 10 percent of the total interference budget to this system, as is sometimes considered reasonable. Although a high (26 dBi) antenna gain was not given in the JTCTS system description, it was assumed that an antenna of this type could be used in a tertiary, or ground-to-ground, link.

All IMT-2000 transmitters considered were narrower in bandwidth than the narrower-bandwidth JTCTS chip rate. A processing loss equal to the ratio of the chip rate to the data rate was applied to the interfering signal level, as described earlier. For each chip rate, the separation was the same for each data rate considered. This is due to the processing loss compensating for the change in noise level. The processing loss is proportional to the data rate, while the noise power, and hence the interference threshold, is inversely proportional to the data rate. See Table E-16.

Table E-16. Separation Distances, in km, from JTCTS Ground Receivers to Preclude Interference from IMT-2000 Transmitters

JTCTS Antenna Gain, (dBi)	JTCTS Receiver Chip Rate (MChips/s)	Data Rate, Mb/s	IMT-2000 Station	
			Mobile	Base
0	5.63	0.3516	13.0	65.4
		1.406	13.0	65.4
	22.5	0.3516	8.1	58.7
		1.406	8.1	58.7
26	5.63	0.3516	33.8	117.3
		1.406	33.8	117.3
	22.5	0.3516	29.6	89.5
		1.406	29.6	89.5

E.5 INTERFERENCE FROM JTCTS INTO IMT-2000 SYSTEMS

E.5.1 Interference from JTCTS Ground-Based Transmitters into IMT-2000 System

Separation distances which may need to be maintained by IMT-2000 receivers to preclude interference from JTCTS ground transmitters were calculated in a manner similar to those corresponding distances for the TACTS/ACMI ground transmitters. The JSC inverse SEM propagation model was used, with the JTCTS characteristics of Tables E-5 and E-7 and the IMT-2000 characteristics of Tables A-4 and A-5. Separation distances were calculated for both the narrowband and wideband JTCTS signal, and each of the four IMT-2000 variations considered, for both mobile and base stations. Results are given in Tables E-17 and E-18. In Table E-17, the separation distances for each version of the IMT-2000, against the wideband JTCTS signal, were the same. In Table E-18, the wideband CDMA version gave slightly more processing loss to the narrowband JTCTS signal, resulting in slightly smaller separation distances, when compared to the other versions, whose separation distances were identical.

Table E-17. Distances, in km, from JTCTS Wideband Ground-Based Transmitters to Preclude Interference to IMT-2000 Receivers

JTCTS Antenna Gain (dBi)	IMT-2000 Station	
	Mobile	Base
IMT-2000 Interference Criterion I/N = -6 dB		
0	32.1	71.3
12	40.3	93.4
26	48.1	154.2
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB		
0	20.8	58.6
12	30.2	68.5
26	39.5	89.2
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB		
0	11.7	48.9
12	22.1	60.0
26	32.8	71.4

Table E-18. Distances, in km, from JTCTS Narrowband Ground-Based Transmitters to Preclude Interference to IMT-2000 Receivers

JTCTS Antenna Gain (dBi)	IMT-2000 Station			
	Mobile		Base	
	WB CDMA	Others	WB CDMA	Others
IMT-2000 Interference Criterion I/N = -6 dB				
0	33.5	35.2	72.3	74.4
12	41.1	42.5	97.1	105.7
26	48.7	50.6	161.7	178.8
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB				
0	21.8	23.9	59.6	61.8
12	31.1	32.8	69.4	71.5
26	40.2	41.7	92.5	100.4
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB				
0	12.6	14.8	50.0	52.4
12	23.1	25.1	60.9	63.0
26	33.5	35.2	72.3	74.4

E.5.2 Interference from JTCTS Airborne Transmitters into IMT-2000 System

The interference from airborne JTCTS transmitters into IMT-2000 receivers was calculated using the same approach and path loss model as was done in a preceding section for the TACTS/ACMI system. As in the preceding section, results are given for both narrowband and wideband JTCTS waveforms. Results are given in Tables E-19 and E-20. Again, for the wideband JTCTS waveform, distances are equal for all IMT-2000 versions, while for the narrowband JTCTS waveform, the wideband CDMA IMT-2000 implementation results in a slightly lower separation distance.

Tables E-19 and E-20 show that the required separation distances are quite high (100 to 400 km), even for the higher interference thresholds. They are higher than those shown for the TACTS/ACMI transmitters, primarily because of the higher EIRP of the JTCTS equipment. Depending on the interference criterion used, coordination to line of sight distances may be necessary to avoid interference from the airborne system to the IMT-2000 receivers.

Table E-19. Required Separation Distances, in km, to Preclude Interference from JTCTS Wideband Airborne Transmitters into IMT-2000 Receivers

IMT-2000 Station					
Mobile			Base		
CDMA WB	CDMA NB	TDMA	CDMA WB	CDMA NB	TDMA
IMT-2000 Interference Criterion I/N = -6 dB					
343.6	343.6	343.6	415.9	415.9	415.9
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB					
187.0	187.0	187.0	399.7	399.7	399.7
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB					
55.2	55.2	55.2	157.3	157.3	157.3

Table E-20. Required Separation Distances, in km, to Preclude Interference from JTCTS Narrowband Airborne Transmitters into IMT-2000 Receivers

IMT-2000 Station					
Mobile			Base		
CDMA WB	CDMA NB	TDMA	CDMA WB	CDMA NB	TDMA
IMT-2000 Interference Criterion I/N = -6 dB					
346	351.4	351.4	417	420	420
IMT-2000 Interference Criterion for S = Sensitivity + 10 dB					
212	283.7	283.7	400	402	402
IMT-2000 Interference Criterion for S = Sensitivity + 20 dB					
62.8	84.1	84.1	179	238	238

E.6 BAND SEGMENTING PLANS

The analysis described in the previous sections assumed no separation in frequency between the IMT-2000 and ACTS systems. If the present band is segmented, with separate but adjacent segments allocated separately to ACTS and IMT-2000 systems, the effect of frequency separation between the two systems becomes of importance.

Two proposed methods for operating within the 1755 to 1850 MHz band were examined briefly, and the feasibility of satisfactory operation of the ACTS and IMT-2000 equipment was assessed.

In the first plan, the 1755-1805 MHz portion of the band remains allocated to ACTS. The rest of the band is allocated to IMT-2000 systems. In the second plan, ACTS and IMT-2000 are allowed to operate in the present band. The ACTS systems operate as they presently do, and the IMT-2000 systems must coordinate in the areas where ACTS operates and where interference is a possibility.

E.6.1 Band Segmenting Plan 1

Under plan 1, the TACTS/ACMI would lose six of the 11 frequencies now available to it across the 1768 to 1840 MHz range. It would lose use of the 1840 MHz (A) or 1830 MHz (B) air-to-ground link transmit frequencies, and four of the six frequencies (1807, 1812, 1817, and 1822 MHz) used for transmitting from the remote ground transmitters to the master receiver. Typically, the TACTS/ACMI uses eight or more frequencies for its necessary functions. Loss of all but the 1755-1805 MHz portion of the band does not appear feasible for satisfactory operation of the present TACTS/ACMI system.

The JTCTS normally uses one to three frequencies between 1710 and 1850 MHz. One frequency is used for air-to-air communications, the primary link. A second frequency is often used for the secondary link, for ground-to-air communications. The third frequency is used for a tertiary data link for ground to ground communications. This link is not always used.

In conversations with JTCTS engineers at SRI International, it has been stated that it may be possible for the JTCTS to operate with two 22.5 MHz channels separated by 5 MHz at the –20 dB points of the spectrum. The total occupied bandwidth would be approximately 22.5 x 2 + 5 = 50 MHz. The third frequency, for the tertiary link, could be reassigned to a different, probably a higher, band. It may be possible that the two channels can operate without mutual interference, as has been stated. However, the effect of JTCTS interactions with IMT-2000 equipment near the edges of the band must also be investigated. A preliminary assessment of the effects of frequency separation was made by generating frequency-distance curves for JTCTS-to-IMT-2000 and IMT-2000-to-JTCTS interactions. The curves generated are for wideband CDMA and wideband JTCTS versions. The middle CDMA interference threshold was used, corresponding to a desired signal 10 dB above sensitivity. These curves are given as Figures E-1 and E-2. Although conservative interference thresholds were used in generating these curves, they show that, at the band edges, 11.25 MHz from the JTCTS wideband center frequency, significant separation distances are needed to avoid interference. Further investigations of these interactions would be necessary to determine the feasibility of this band segmenting plan.

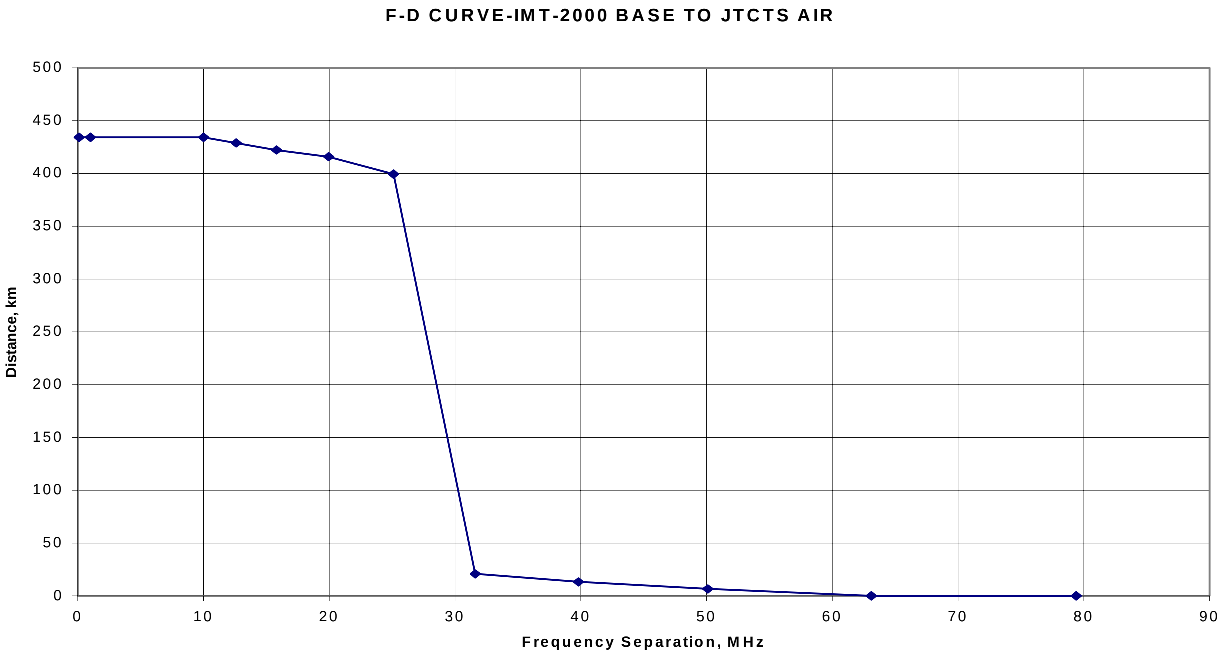

Figure E-1. Frequency-Distance Curve for JTCTS Airborne to IMT-2000 Interaction

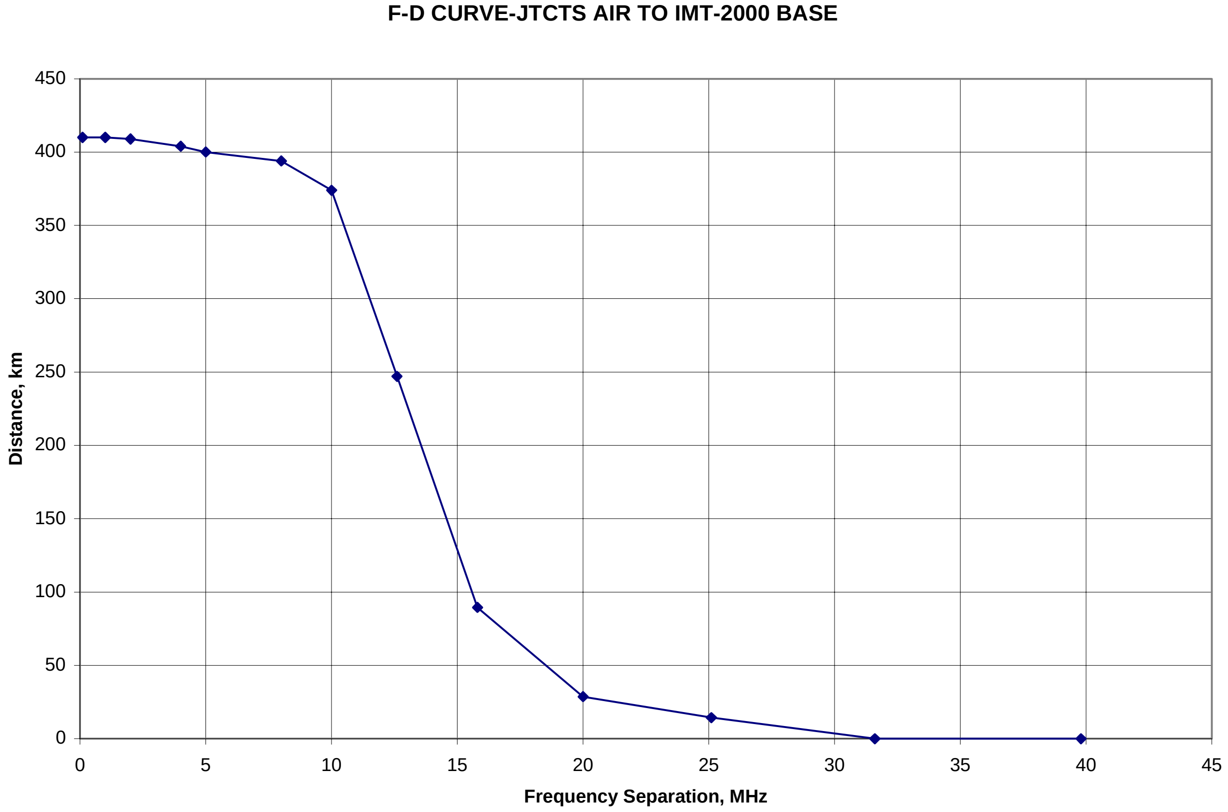

Figure E-2. Frequency-Distance Curve for IMT-2000 to JTCTS Airborne Interaction

E.6.2 Band Segmenting Plan 2

In plan 2, which involves coordination within the same band, IMT-2000 systems would be forced to coordinate their operation in areas where present ACTS systems operate and interference is a possibility. In the first segment of the band to be made available, 1710 to 1755 MHz, no TACTS/ACMI frequencies exist, and it may be possible for JTCTS to avoid this range. For the other segments (1755 to 1780 and 1780 to 1790 MHz), airborne and ground-based TACTS/ACMI frequencies are used. The results of the previous sharing analysis show that, for the airborne ACTS transmitters, coordination distances to avoid interference to an IMT-2000 receiver are sometimes at line-of-sight distances (400 km for 9000 m altitude). Distances needed to avoid interference from aggregate IMT-2000 environments to an airborne ACTS receiver are more difficult to calculate. However, with a single metropolitan area the size of Las Vegas, NV, and ignoring the effects of other cities, preliminary calculations indicate that separation distances of the same magnitude or larger may be needed.

E.6.3 Band Segmenting Conclusions

Interference problems exist in implementing both segmenting plans 1 and 2. With plan 1, operation of the present TACTS/ACMI is not feasible. Operation of JTCTS, with the tertiary data link assigned to a different band, may be feasible. However, further investigation is needed to verify this conclusion.

E.7 CONCLUSIONS

Because of the large separation distances needed to avoid interference from airborne ACTS transmitters to IMT-2000 receivers, and because of the effect of the aggregate IMT-2000 ground environment on the link margins of the airborne ACTS receivers, sharing of the two systems, without frequency separation, does not appear feasible.

Interference between airborne ACTS transmitters and IMT-2000 receivers and between the aggregate IMT-2000 environment and ACTS airborne receivers seem to be the worst, or most limiting, cases, for band sharing.

A 10 dB reduction of aggregate interference power, as might be associated with an incomplete buildup of a mature IMT-2000 environment, still results in negative link margins for TACTS/ACMI and JTCTS airborne receivers.

For ground-to-ground interactions, separation distances to avoid interference appear to be of the same order of magnitude for ACTS-to-IMT-2000 and IMT-2000-to-ACTS interactions. Effects on system operation depend on interference thresholds used and the location of the ACTS ground equipment.

Of the band-segmenting plans proposed, plan 1 involves use of only the 1755-1805 portion of the band. Operation of the TACTS/ACMI does not appear feasible with this plan. Operation of the JTCTS may be possible with reassignment of one of the three channels. Interactions of JTCTS with IMT-2000 equipment in adjacent bands need to be investigated further before feasibility of this option can be demonstrated.

Segmentation plan 2 involves coordination of IMT-2000 operations in regions where ACTS systems presently operate and interference is possible. For the portions of the band above 1755 MHz, preliminary analysis, as discussed in this report, indicates that, because of the use of airborne ACTS transmitters and receivers, coordination distances from flight areas may exceed 400 km, making this plan difficult to implement.

E.8 MITIGATION TECHNIQUES

Possible methods to mitigate interference between IMT-2000 and ACTS equipment include the following:

- Coordination of antenna orientation of IMT-2000 base stations with the location of the training ranges. The mainbeams of the IMT-2000 antennas should not point in the direction of training range ground stations or of major flight activity, and the IMT-2000 base stations should not be illuminated by the mainbeams of high-gain ACTS ground station antennas.
- Coordination of training range aircraft training schedules with IMT-2000 operations, such that IMT-2000 power levels, frequencies, or antenna orientations could be adjusted to avoid mutual interference.
- Use of polarization diversity between IMT-2000 base stations and ACTS equipment, to reduce interference levels for mainbeam-to-mainbeam interactions between IMT-2000 and ACTS equipment.