APPENDIX C1: TECHNICAL EVALUATION OF 2 GHz MSS ATC PROPOSALS

1.0 Assessment of Assumptions Used in Technical Analysis

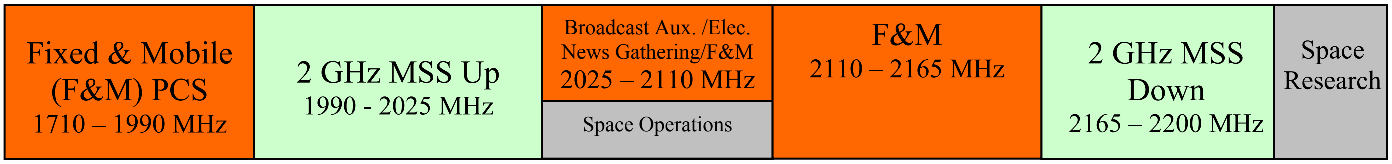
ICO, a 2 GHz mobile satellite service (MSS) licensee, submitted a proposal for an Ancillary Terrestrial Component (ATC) system to operate in conjunction with its MSS System. In its ATC proposal, ICO does not specifically define which bands it would use for the base stations (BS) and user mobile terminal (MT) transmitters. Instead, ICO lists four possible modes of implementing the ATC system. As shown in the following Table, the consideration of the four possible ATC modes requires that proposed MT and BS transmitter operations be analyzed for compatibility in both the MSS uplink (1990-2025 MHz) and MSS downlink (2165-2200 MHz) frequency bands.

Implementation Scheme	MSS Uplink Band	MSS Downlink Band
Uplink Hybrid	BS and MT	
Downlink Hybrid		BS and MT
Forward Band	MT	BS
Reverse Band	BS	MT

In addition to the MSS uplink and downlink bands, the ICO ATC proposal potentially affects the operations of systems in adjacent frequency bands shown in the Figure 1 below. In general there are two different situations: adjacent assignment and adjacent allocation. This appendix analyzes the potential interference to MSS systems operating within the MSS frequency allocation on MSS assignments adjacent to ICO's MSS selected assignment and to other types of communication systems operating in allocations adjacent to the MSS allocations.

The adjacent allocation situation occurs at the allocation boundary between the MSS and the services that operate in the adjacent bands. The adjacent assignment situation occurs between ICO and the MSS systems that will occupy adjacent MSS assignments within the MSS Allocation. Co-frequency sharing between an MSS system and the terrestrial fixed systems which currently occupy the 2 GHz MSS allocations has been addressed in the 2 GHz Service Rules Report and Order and is not a topic of this Technical Appendix.[1]

Figure 1 - 2 GHz MSS and Adjacent Allocated Bands



Fixed & Mobile (F&M) PCS 1710 – 1990 MHz	2 GHz MSS Up 1990 - 2025 MHz	Broadcast Aux. /Elec. News Gathering/F&M 2025 – 2110 MHz Space Operations	F&M 2110 – 2165 MHz	2 GHz MSS Down 2165 – 2200 MHz	Space Research

1.1 Out-of-Band Emission Levels

ICO states that the ATC transmitters will either operate in the ICO MSS assignment or, on a secondary basis, within the MSS assignment of another MSS licensee. In the Forward Band and Reverse Band modes both MT and BS transmitters will operate within the ICO MSS assignments. In the Uplink Hybrid and Downlink Hybrid modes ICO states that the MT and BS would both transmit in the MSS uplink and

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[1] *See Establishment of Policies and Service Rules for the Mobile Satellite Service in the 2 GHz Band*, IB Docket No. 99-81, Report and Order, 15 FCC Rcd 16127 (2000) (*2 GHz MSS Rules Order*).

downlink, respectively. The co-channel compatibility of the ICO ATC transmitters and other MSS systems is not the subject of this appendix. This appendix specifically addresses the out-of-band compatibility between the ICO ATC transmitters and other MSS systems and communication systems operating in frequency allocations adjacent to the MSS allocations.

The ICO ATC proposal provided technical details of a 3G PCS system as a representative ATC system.[2] The 3G system selected by ICO was CDMA2000. The out-of-channel emission values associated with the CDMA2000 system are shown in Table 1.1.A.[3]

Table 1.1.A ICO Proposed ATC Out-of-Band Emission Values

Out-of-Channel EIRP	MT	BS
700-750 kHz offset from center	-53.3 dBW/4kHz	-16.3 dBW/4kHz
>750 kHz offset from center	-93.5 dBW/4kHz	-56.5 dBW/4kHz

In January of 2002, ICO submitted an ex parte letter which readdressed the out-of-channel emissions from its proposed ATC system. The following table, Table 1.1.B, shows the out-of-band emission limits proposed by ICO in its *ex parte* comments.[4] These are emission levels that ICO states would occur at the edge of its MSS assignment.

Table 1.1.B ICO Out-of-Band Values

Equipment	MSS Uplink Band	MSS Downlink Band
MSS User Terminal in ATC Mode	-67.0 dBW/4kHz	-119.6 dBW/4kHz
ATC Base Station	-67.0 dBW/4kHz	-100.6dBW/4kHz

ICO states that "[t]hese limits should be measured at the transmitter (whether base station or user MT) in the receive band assigned to the adjacent MSS systems. The limits for MSS uplink spectrum are identical to the PCS emission limits in Section 24.238 of the Commission's Rules. The limits for the downlink spectrum are more stringent, in recognition of the fact that ATC operations in MSS downlink spectrum likely represents a greater interference threat to MSS operations."[5] ICO is correct that for a PCS system with a transmit power of 1 Watt, the limiting emission it quotes for the MSS uplink band is consistent with section 24.238. The limits listed for the MSS downlink band are significantly below the level specified by section 24.238.

The limits included in Table 1.1.A were used by other commenters to evaluate the potential impact of the proposed ICO ATC system on their systems. The later limits, contained in Table 1.1.B, are significantly different than those in Table 1.1.A and will be used in our analyses to assess the potential interference between the ICO ATC transmitters and MSS systems in adjacent bands and other systems in adjacent allocations.

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[2] ICO Mar. 8, 2001 *Ex Parte* Letter, App. B at 10.

[3] ICO Mar. 8, 2001 *Ex Parte* Letter, App. B at 11.

[4] ICO Apr. 10, 2002 *Ex Parte* Letter at 2.

[5] ICO Apr. 10, 2002 *Ex Parte* Letter at 2.

1.2 Other Assumptions Used in Technical Analysis

1.2.1 Voice Activation

ICO states that additional factors may reduce the level of out-of-band (OOB) emissions from both the ATC MTs and BS transmitters. In particular, ICO asserts that a voice activation factor of 4 dB,[6] or 40%, is appropriate when dealing with a population of PCS-like transmitters. While the actual value of the voice activations factor will depend upon the level of background noise experienced by the users, typical values do range from 1 to 4 dB.[7]

1.2.2 Power Control

ICO also claims that a power control factor of 4.77 dB is appropriate and conservative to use with a large population of PCS-like transmitters.[8] Other commenters in this proceeding have used values of a power control factor ranging from 2 to 6 dB. Our independent evaluation of terrestrial cellular network power control leads us to the conclusion that ATC networks would incorporate a power control factor of 10 dB, or greater, in sharing analyses for the ATC network.[9] Several factors that minimize the BS and MT power usage including the following: structural attenuation,[10] BS/MT range variation and body blockage. The purpose of reducing the power usage is to reduce the cell-to-cell interference and to prolong MT battery life. Typical structural attenuation factors are on the order of 10 dB or greater; BS/MT range variations are on the order of 6 dB; and body blockage is approximately 2-4 dB. The actual dynamic range of the power control system is expected to be greater than the sum of the individual attenuation factors. We use a 10 dB power control factor for MT transmissions in our analysis of 2 GHz ATC operations. A more detailed discussion of these factors is provided in Appendix C2 1.3.

1.2.3 Frequency Polarization Isolation

Some frequency polarization isolation will exist between a transmitter and receiver using different polarization schemes. In comments submitted with regard to this proceeding Inmarsat references a value of 1.4 dB for polarization isolation for all cases of linear to circular, non-identical polarization mismatch between a PCS-like transmitter and a satellite transmitter.[11] MSV argued that when considering an ensemble of randomly oriented linear emitters received by a circularly polarized receiver, a value of 3 dB would be more appropriate to use.[12] Because the orientation of the linear transmit ATC antennas will not be truly random,[13] a more conservative 1.4 dB number proposed by Inmarsat is taken into account in our

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[6] *See* ICO Jan. 29, 2002 *Ex Parte* Letter at 3.

[7] *See infra* App. C2, L-band Technical App., § 1.

[8] *See* ICO Jan. 29, 2002 *Ex Parte* Letter at 4.

[9] *See infra* App. C2, § 1.3 for a detailed discussion on the use of power control in cellular systems.

[10] By "structural attenuation" we mean the signal attenuation that takes place when an MT transmits within a building, automobile or other structure that completely encloses the MT. We differentiate between "structural attenuation" and "outdoor blockage" of the line-of-sight propagation path between a transmitter and a satellite receiver caused by obstacles such as buildings and trees.

[11] Inmarsat Comments at 27.

[12] MSV Reply at 8.

[13] It is expected that the ATC handset antennas will be oriented in some distribution about the local vertical and not have an equal probability of being oriented in all directions.

analyses. We believe that these arguments, made with respect to L-band MSS operations, are also applicable to 2 GHz MSS.

1.2.4 Receiver Saturation Level

Some parties have argued that their mobile earth stations (MES) will "overload," or saturate, when exposed to -120 dBW of interfering power within the RF band-pass of the receiver.[14] This level is equivalent to -90 dBm. Other parties have provided measurements of an L-band terminal that showed that saturation did not occur until the input power reached about -45 dBm, some 45 dB higher than -90 dBm.[15] Additionally, some parties have quoted the Radio Technical Committee on Aeronautics (RTCA) as having a standard for -50 dBm for airborne terminals. Given these potential values for saturation we feel that the use of -50 dBm for airborne terminals and -60 dBm for mass produced terrestrial receivers is reasonable. Therefore, we will use a value of -60 dBm in our 2 GHz analyses, except in cases where one of the parties specifically states that it can use a receiver that is less susceptible to saturation.

2.0 Intra-Service (Adjacent Assignment) Interference Analyses

The 2 GHz processing round resulted in the licensing of eight (8) MSS systems in 70 MHz of spectrum. As contained in the 2 GHz R&O,[16] this spectrum will be divided among the licensees who are successful in implementing their systems. Upon the launch of its first satellite, an MSS licensee must declare a portion of the 2 GHz spectrum as "home" spectrum. Each licensee will also be permitted to operate in additional 2 GHz MSS spectrum on a non-harmful-interference basis. Because each MSS systems will operate alone in its home spectrum, intra-service sharing is not a co-frequency sharing situation. There is however, a potential for interference to the MSS systems operating in the adjacent frequency assignment. Boeing is the only MSS licensee that has provided detailed comments concerning the potential that the ICO ATC system may cause interference to another 2 GHz MSS system. We evaluate the impact that 2 GHz ATC as proposed by ICO would have on Boeing's MSS system.

2.1 MSS Uplink Band (1990-2025 MHz)

ICO has proposed three possible ATC modes that would place transmitters in the MSS uplink band;

(1) Forward Band Mode that would implement ATC MTs in the MSS uplink band;

(2) Reverse Band Mode that would put ATC base stations in the MSS uplink band; and

(3) Uplink Duplex Mode that implements both the ATC MT and BS in the MSS uplink band.

The following addresses the potential for intra-service, adjacent channel interference among the MT and BS transmitters in the MSS uplink band.

2.1.1 Analysis of Potential Interference to Adjacent MSS Assignments – MSS Uplink Band

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[14] Inmarsat Comments, Technical Annex § 3.3.1. When relevant, we distinguish between mobile earth stations (MES) and mobile terminals (MTs). We use the term "MES" to identify terminals that communicate only with an MSS system. We use the term "MT" to identify terminals that communicate with either the MSS system or its ATC.

[15] *See* MSV Reply, Technical App. at 14.

[16] *2 GHz MSS Rules Order*, 15 FCC Rcd at 16174-81, ¶¶ 99-116.

Boeing submitted initial comments indicating that, based upon a number of assumptions, it is concerned about possible interference from the ATC BS to satellite uplink receivers.[17] However, it indicates that no problem should be encountered from the ATC MT to satellite uplinks. As mentioned earlier, this scenario is an adjacent channel sharing situation, as each MSS system will be assigned its own home spectrum and must operate on a non-interference basis in any other part of the MSS allocation. The following sections compare Boeing's analysis with our independent analysis.

2.1.2 Interference to Boeing Satellite Receiver from ATC Base Stations

Boeing provides a link calculation which uses a 6% increase in the satellite receiver noise as the interference criteria.[18] The result of the Boeing calculations indicate a positive margin at the satellite of about 5 dB. Based upon this margin Boeing expressed concern about the potential for interference and suggested that an aggregate base station power limit might be appropriate.

The Boeing calculation describes an interference link from a number of base stations at the edge of coverage (10 degree elevation) of the Boeing MSS satellite spot beam. It assumes that there are 500 base stations and that they are located on this 10 degree elevation contour. The third column of Table 2.1.2.A is reproduced from the Boeing Comments and is included for comparison purposes. The Boeing analysis is based upon the satellite being visible at the base station at an elevation angle of 10 degrees and corresponds to a calculated path loss of –186.3 dB as shown in the table. The Boeing analysis also assumes that the mainbeam EIRP of all 500 base stations are coupled into the mainbeam of the satellite receive antenna at the base station mainbeam gain. Based upon the 10 degree elevation angle and a -2.5 degree base station antenna tilt proposed by ICO,[19] the angle between the base station peak gain direction and the Boeing satellite would be 12.5 degrees vertically. Using the reference radiation pattern in ITU-R Rec. F.1336, shown in Figure 2.1.2.A, at 12.5 degrees off axis, the base station antenna can be expected to have about 11.5 dB of gain discrimination from the main beam gain. Additionally, the ATC BS out-of-band emission has been reduced from the -56.6 dBW/4kHz in the initial ICO proposal, and assumed by Boeing, to the value in Table 1.1.A. These two factors combine to increase the calculated margin from the 4.6 dB calculated by Boeing to 26.6 dB as shown in the fourth column of Table 2.1.2.A.

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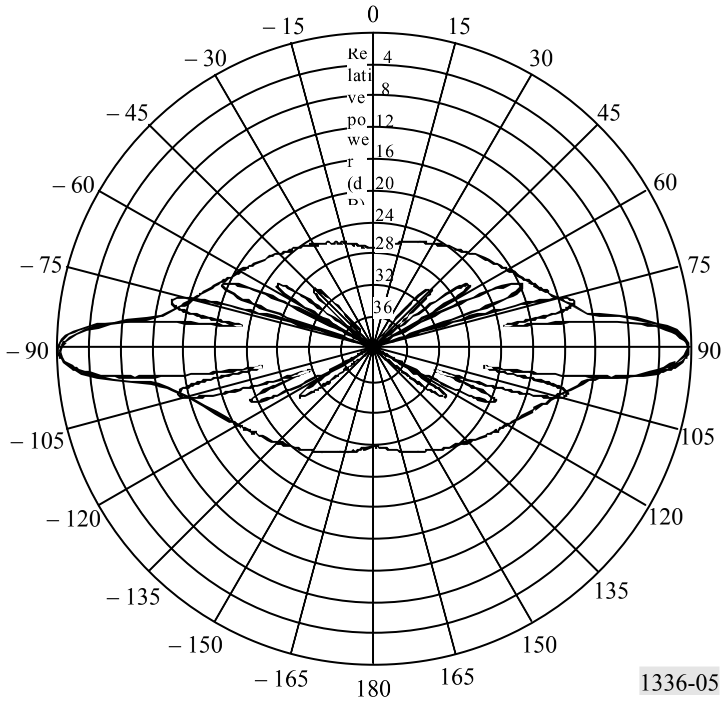
[17] *See generally* Boeing Comments, App. A.

[18] *See* Boeing Comments, App. A at 5.

[19] This is typical of CDMA2000 base stations. *See* ICO Mar. 8, 2001 *Ex Parte* Letter, Annex B at 11.

Figure 2.1.2.A Antenna Radiation Pattern of Rec. ITU-R F.1336

Comparison of measured pattern and reference radiation pattern envelope for an omnidirectional antenna with 11 dBi gain and operating in the band 928-944 MHz, $k = 0$



ICO states that it will implement a maximum gain suppression for base station antennas of 25 dB.[20] This value appears to be feasible to meet and is supported by the measured antenna pattern in Figure 2.1.2.A. This indicates that the link analysis presented in the fourth column of Table 2.1.2.A is conservative. Additionally, no account has been taken of the polarization isolation that would exist between the ICO base station and the Boeing satellite receiver. Boeing's analysis suggests that there should be a limit on the aggregate base station power. According to our analysis, such a limit is not necessary.

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[20] ICO Mar. 8, 2001 *Ex Parte* Letter, Annex B at 17.

Table 2.1.2.A - Interference to Boeing Satellite Receiver from ATC Base Station

Parameters	Units	Boeing Analysis	Modified Boeing Analysis
Frequency	(GHz)	2.0	2.0
ICO OOB Base Station Emission	(dBW/4kHz)	-56.5	-67.0
Number of Base Stations Visible	(#)	500	500
OOB Reference Bandwidth	(kHz)	4.0	4.0
OOB Emission Density (500 Stations)	(dBW/Hz)	-65.5	-76.0
Satellite Altitude	(km)	20182	20182
Minimum Elevation Angle	(deg)	10	10
Range to Satellite	(km)	24699	24699
Path Loss	(dB)	-186.3	-186.3
Base Station Gain Isolation	(dB)	0	-11.5
Satellite Receive Gain	(dBi)	33.0	33.0
Polarization Isolation	(dB)	0.0	0.0
Interference Density (Io)	(dBW/Hz)	-218.8	-240.8
Satellite Receive Noise Temp	(K)	450	450
Noise Density (No)	(dBW/Hz)	-202.1	-202.1
Interference to Noise Io/No	(dB)	-16.8	-38.8
Io/No Required for 6% Increase in No	(dB)	-12.2	-12.2
Margin	(dB)	4.6	26.6

2.1.3 Interference to Boeing Satellite Receiver from ATC User Terminals

Boeing's initial analysis[21] showed that it did not expect interference problems from ATC MTs in the satellite uplink band. Its calculation assumed 10,000 MTs visible in the Boeing satellite antenna beam. The link calculation predicted a margin of 25 dB at the satellite receiver. However, this analysis was based upon the out-of-channel emission value of –93.5 dBW/4 kHz for the MT contained in the initial ICO proposal. In its latest filing[22] describing out-of-band emission levels, ICO has stated that the out-of-channel emission from a MT in the MSS uplink band would be -67.0 dBW/4kHz. Table 2.1.3.A contains a copy of the Boeing analysis, in the third column, and a similar analysis using the most recent ICO out-of-channel emission values. Incorporated in the right-most column is a 1.4 dB value for frequency polarization isolation, which applies to the case of multiple linear transmitters being received by a circularly polarized receiver. The right-most column of Table 2.1.4.A shows that, using the latest ICO MT out-of-channel values, there is virtually no margin at the Boeing satellite receiver. Therefore, the use of the Section 24.238 emission limitations, alone, for the ICO MT, creates the potential for interference to occur to the Boeing satellite receiver.

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[21] Boeing Comments Oct. 19, 2001, App. A, Table 4.

[22] *See* ICO *Ex Parte* Letter, April 10, 2002 at 2.

Table 2.1.3.A - Interference to Boeing Satellite Receiver from ATC User Terminals

Parameters	Units	Boeing	Staff
Frequency	(GHz)	2.0	2.0
ICO OOB ATC MT emission	(dBW/4kHz)	-93.5	-67.0
Number Terminal Stations Visible	(#)	10000	10000
OOB Reference Bandwidth	(kHz)	4.0	4.0
OOB Emission Density 10,000 Terminal	(dBW/Hz)	-89.5	-63.0
Satellite Altitude	(km)	20182	20182
Elevation Angle	(Deg)	90	90
Range to Satellite	(km)	20182	20182
Path Loss to Satellite	(dB)	-184.6	-184.6
Satellite Receive Gain	(dBi)	34.8	34.8
Polarization Isolation	(dB)	0.0	-1.4
Interference Density (Io)	(dBW/Hz)	-239.3	-214.2
Satellite Receive Noise Temp	(K)	450	450
Noise Density (No)	(dBW/Hz)	-202.1	-202.1
Interference to Noise Io/No	(dB)	-37.2	-12.1
Io/No Required for 6% Delta T/T	(dB)	-12.2	-12.2
Margin	(dB)	25.0	-0.1

As shown in Table 2.1.3.A the section 24.238 OOB limits used with Boeing's link budget essentially results in no link margin. This analysis, however, does not include the mitigating effects of ATC power control and voice activation on sharing with the Boeing system. These two factors combine to decrease the average power emitted towards the Boeing satellite receiver by 8.77 dB according to the values for these factors proposed by ICO. Our independent review on the use of power control in ATC networks suggests that a factor of 10 dB or more would be appropriate to use.[23] Incorporating these two factors into the analysis reduces the increase in noise at the Boeing receiver to less than 1% increase in effective receiver noise temperature. This level of interference to the Boeing satellite receiver should be acceptable.

2.2 MSS Downlink Band (2165-2200 MHz)

2.2.1 Analysis of Adjacent MSS assignments (Boeing airborne receivers)

Boeing has submitted comments indicating that it is concerned about potential interference to its 2 GHz downlinks (specifically, from the ATC BS and MT transmitters to Boeing's MSS aircraft receiver). As mentioned previously these scenarios are actually out-of-band sharing situations, because each MSS system will be assigned its own home spectrum.

The next two sections compare the Boeing downlink interference calculations which were performed using the OOB values contained in the initial ICO proposal with a similar calculation using ICO's latest

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[23] *See* App. C2, § 1.3.

out-of-band values at the band edge. These calculations consider potential interference to a Boeing receiver while the aircraft is on the ground at an airport. The final value calculated is the distance between the ICO transmitter and the aircraft on which the Boeing receiver is mounted. Boeing used an interference criterion of a 6% increase in the receiver noise floor. While there is no regulation that codifies a 6% terrestrial receiver noise increase as being harmful interference, it is used in this case, to gauge the interference potential.

2.2.2 Potential Interference to Boeing Airborne Receivers from ATC Base stations

Table 2.2.2.A reproduces the Boeing calculations in the third column from the left. This link analysis, assumes that the out-of-band emission from an ICO ATC base station is –56.5 dBW/4 kHz. ICO has stated that it will limit emissions at the band edge to –100.6 dBW/4 kHz for BS. The Boeing analysis indicated that a separation distance of some 21.9 km would be required between the ATC base station and the airborne Boeing receiver for the interference level to produce an increase of 6% in the receiver noise floor or less. Use of the ICO band-edge values reduces this required separation distance to 0.19 km (630 ft). For normal in-flight operations an aircraft-to-base station separation distance of 0.19 km would be considered to be sufficient to ensure that no interference would occur. This is particularly true because the selected interference criterion of an increase in effective receiver noise temperature of 6% would not cause a serious degradation in the performance of the Boeing MSS system. However, the possibility exists that a base station could be placed near an airport. In this situation care will have to be exercised to ensure that the base station is located at least 630 feet from a runway area or an area in which an aircraft may be parked or taxing.

Table 2.2.2.A - Interference to Aircraft Terminal from ATC Base Station

Parameters	Units	Boeing Analysis	Staff Analysis
Frequency	(GHz)	2.0	2.0
Area of Isotope	(dBm^2)	-27.5	-27.5
Noise Temperature	(K)	200	200
Noise Density (No)	(dBW/Hz)	-205.6	-205.6
Interference Criteria Io/No	(dB)	-12.2	-12.2
Number of ICO Transmitters	(#)	1	2
Interference Density (Io)	(dBW/Hz)	-217.8	-217.8
Base Station OOB, Boeing Value	(dBW/4 kHz)	-56.5	
ICO Supplied OOB Value	(dBW/4 kHz)		-100.6
Transmitter OOB Emission	(dBW/Hz)	-92.5	-136.6
Antenna Gain (Boeing User Terminal)	(dBi)	0.0	0.0
Polarization Isolation	(dB)	0.0	0.0
Required Propagation Loss	(dB)	-125.3	-84.2
Required Separation Range	(km)	21.9	0.19
Required Separation Range	(ft)	71,800	630

2.2.3 Potential Interference to Aircraft Receivers from ATC MT

Boeing also commented that, based upon the OOB values contained in the ICO application, the emission from 6 ATC MTs could increase the noise floor of the aircraft receiver by 6% if the MTs where all located at a distance of 0.8 km from the aircraft. Table 2.2.3.A, below, shows both the Boeing calculation and our calculation assuming ATC MTs are restricted to the band-edge values supplied in the ICO *ex parte* letter. The required separation distance is reduced to 0.03 km (105 ft) for the ATC MT and 0.02 km

(56 ft) for MSS user terminals. The probability of having 6 simultaneously transmitting MTs within 100 feet of an aircraft is small. This is particularly true because MTs in the terminal building would experience building blockage and MTs on the airport tarmac should be operated only by airport personnel. Again, the selected interference criteria of an increase in noise temperature of 6% would not cause significant interference to the Boeing system under transient conditions and this situation should not cause a problem for the Boeing MSS receiver.

Table 2.2.3.A - Interference to Aircraft Terminals from ATC MTs

Parameters	Units	Boeing Analysis	ICO MT	ICO MES
Frequency	(GHz)	2.0	2.0	2.0
Area of Isotope	(dBm^2)	-27.5	-27.5	-27.5
Noise Temperature	(K)	200	200	200
Noise Density (No)	(dBW/Hz)	-205.6	-205.6	-205.6
Interference Criteria Io/No	(dB)	-12.2	-12.2	-12.2
Number of Mobile Transmitters	(#)	6	6	6
Acceptable Io (6% noise increase)	(dBW/Hz)	-217.8	-217.8	-217.8
Polarization Isolation	(dB)	0.0	1.4	0.0
Boeing Value for OOB Emission	(dBW/4 kHz)	-93.5		
ICO OOB Value	(dBW/4 kHz)		-119.6	-126.5[24]
Number of Transmitters	(dB)	7.8	7.8	7.8
Out-of-Band Emission Level	(dBW/Hz)	-121.7	-147.8	-154.7
Antenna Gain (Boeing UT)	(dBi)	0.0	0.0	0.0
Required Prop Loss	(dB)	-96.1	-63.1	-63.1
Required Separation Range	(Km)	0.8	0.03	0.02
Required Separation Range	(feet)	2485	104	56

2.2.4 Saturation of Boeing MSS Receivers

Boeing has expressed concern[25] over the possibility of both ICO MTs and BSs saturating a Boeing MSS receiver. The Commission's 2 GHz MSS rules require that the MSS transceiver be capable of tuning across at least 70% of the United States 2 GHz MSS allocation.[26] Boeing explains that the MSS receiver needs to tune across the entire available 2 GHz downlink band. This leaves the front end of the Boeing receiver open to the full power of transmitters from the ICO ATC system. Boeing specifically states that it is using a receiver designed to saturate at -80 dBW, or -50 dBm.

2.2.4.1 Saturation of Boeing MSS Receivers from ICO ATC MT

The possibility of ICO ATC MT interfering with, or saturating, Boeing MES receivers can only occur in ICO Reverse-Band or Downlink-Hybrid Modes. Boeing's analysis of ATC MT[27] is reflected in Table

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[24] Out-of-band emission from an ICO MSS terminals are identified in 47 C.F.R. § 25.202(f).

[25] Boeing Supplemental Comments at 10.

[26] *See* 47 C.F.R. § 25.143(b)(2)(ii)(2001).

[27] *See* Boeing April 5, 2002 *Ex Parte* Letter at 11.

2.2.4.1.A below. The analysis indicates that the Boeing MSS receiver will experience saturation if it is within 96 feet of an ICO ATC MT and clearly visible to the MT. It should be noted that our analysis assumes an MT EIRP of one watt, while Boeing assumed -10 dBW.

Table 2.2.4.1.A Saturation of Boeing receivers from ATC MTs

Parameters	Units	Value
Frequency	(GHz)	2.185
Transmit Power	(dBW)	0.0
Boeing Receiver Saturation Power	(dBW)	-80.0
Polarization Isolation	(dB)	1.4
Antenna Gain	(dBi)	0.0
Required Propagation Loss	(dB)	78.6
Required Separation Distance	(m)	93
Required Separation Distance	(ft)	305

While Boeing's MSS receivers will be located on aircraft, the same can not be said of all of the other potential 2 GHz MSS licensees. Additionally, as we said earlier we would assume a saturation level of -60 dBm unless one of the parties, like Boeing, specifically stated that it was using a receiver with more robust saturation characteristics. If the saturation level of -60 dBm is used, a calculation similar to that of Table 2.2.4.1.A yields a required separation distance of 295 meters or 970 feet. While Boeing states that "it is exploring the possibility of making modifications to its receivers," there is no assurance that other MSS licensees will do the same.

ICO responds to Boeing by stating that it "believe[s] that with an appropriate selection of "off-the-shelf" receiver components and a prudent design, saturation levels on the order of -55 dBW to -50 dBW are achievable for any MSS [MES]."[28] These levels are equivalent to -25 dBm and -20 dBm respectively. There is no technical information presented in the record to support ICO's claim and it would be unreasonable to require all MSS licensees to design to these saturation levels at this time. ICO additionally indicates that factors such as voice activation and power control will reduce the effect of saturation on MES receivers. These factors are taken into account when large quantities of ATC MTs are being considered. In this case the saturation is caused by a single MT and these factors can not be used to mitigate the potential interference in this situation.

2.2.4.2 Saturation of Boeing MSS Receivers from ICO ATC BSs

Boeing provides an analysis of the potential for saturation of its MSS receivers from ICO BS transmitters[29] and comes to the conclusion that saturation is possible when the base station is within about 2 km[30] of the MSS receiver. The Boeing analysis assumes mainbeam coupling of the BS antenna and an airborne MSS receiver. The distance at which the receiver will receive sufficient power to undergo saturation will depend upon a number of factors such as the actual BS antenna pattern, the height of the BS tower and the presence or absence of intervening structures. Recommendation ITU-R F.1336

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[28] *See* ICO April 10, 2002 *Ex Parte* Letter, Attach. C.

[29] *See* Boeing April 5, 2002 *Ex Parte* Letter at 12.

[30] The precise number calculated by Boeing was 2.068 km.

provides a reference antenna pattern that can be used near the mainbeam of the BS transmitter. If the Boeing MSS receiver is assumed to be mounted on the top of an aircraft (7.5 m off the ground) and the ATC BS tower is 30 meters high, then the distance at which the receiver saturates will depend on the tilt angle of the BS antenna. Table 2.2.4.2.A shows the distance at which saturation would occur for a -2.5 degree downtilt of the BS antenna.

Table 2.2.4.2.A shows that the power flux of -51.8 dBW/m^2 is equivalent to the Boeing saturation level of -50 dBm. The lower part of the Table shows the distance required for the power flux from the ATC base station to drop-off to -51.8 dBW/m^2. For a BS antenna tilt of -2.5 degrees, the tilt angle proposed by ICO, the power flux will be at -51.8 dBW/m^2 approximately 1126 m from the antenna.

Table 2.2.4.2.A Calculation of Necessary Separation Distance for a Boeing MSS Receiver and ICO BS

Parameters	Units	Value
Frequency	(GHz)	2.185
Assumed Saturation level	(dBm)	-50
Conversion to dBW	(dBm)	-30
Assumed Saturation level	(dBW)	-80
Receive Antenna Gain	(dBi)	0
Isotropic Antenna Area	(dBm^2)	-28.2
Power Flux at Saturation	(dBW/m^2)	-51.8
Base Station Height	(m)	30
MSS Terminals Height	(m)	7.5
BS Tilt Angle	(Degrees)	-2.5
BS Off-Boresight Angle	(Degrees)	1.36
Mainbeam EIRP	(dBW)	27
BS Antenna Discrimination	(dB)	-6.8
EIRP towards MSS Receiver	(dBW)	20.2
Range to MSS Receiver	(m)	1126
Path Loss	(dB/ m^2)	-72.0
Power Flux at Boeing Receiver	(dBW/m^2)	-51.8

Performing the same calculation for a "hand held" MSS receiver with a more typical saturation level of -60 dBm produces the calculations shown in Table 2.2.4.2.B. In this case the MSS receiver is 1.5 m high while the BS antenna is modeled as being 30 m high. The separation distance for the BS antenna tilt angle of -2.5 degrees is over 2 km.

Table 2.2.4.2.B Calculation of Necessary Separation Distance for Typical Handheld MSS Receiver

Parameters	Units	Value
Frequency	(GHz)	2.185
Assumed Saturation level	(dBm)	-60
Conversion dBm to dBW	(dBm)	-30
Assumed Saturation level	(dBW)	-90
Receive Antenna Gain	(dBi)	0
Isotropic Antenna Area	(dBm^2)	-28.2
Power Flux at Saturation	(dBW/m^2)	-61.8
Base Station Height	(m)	30
MSS Terminals Height	(m)	1.5
BS Tilt Angle	(Degrees)	-2.5
BS Off-Boresight Angle	(Degrees)	1.7
Mainbeam EIRP	(dBW)	27
BS Antenna Discrimination	(dB)	-11.2
EIRP towards MSS Receiver	(dBW)	15.8
Range to MSS Receiver	(m)	2148
Path Loss	(dB/m^2)	-77.6
Power Flux at MSS Receiver	(dBW/m^2)	-61.8

We agree with Boeing that, in areas in which free-space propagation is the dominant mode of propagation, the ATC BS should observe a separation distance to protect MSS receivers from possible saturation. For a -2.5 degree BS antenna tilt, the separation distance would be about 2 km. Alternately, the BS could be implemented in a way to reduce the area in which the power flux is greater than -61.8 dBW/m^2.

In many urban areas free-space propagation will not be the dominant mode of propagation. Some parties to this proceeding have used free-space loss to determine the expected attenuation from the ATC BS to a MES. Others have used the Walfisch-Ikegami (WI) propagation model which typically results in a higher attenuation for the same case. The WI model is based upon the expected propagation loss in an urban/city setting that consists of relatively tall buildings. The National Institute of Standards and Technology (NIST) has developed a computer program that compares a number of different propagation models including the WI model. Using the NIST software,[31] propagation loss values for a 1 km path of 136.4 dB are calculated from the Hata-city model, 131.4 dB from the CCIR (now ITU-R) model and 171.7 dB is calculated from the WI non-LOS model. All of these predicted losses are well above the 105.2 dB total free space losses[32] resulting from Tables 2.2.4.2.A and Table 2.2.4.2.B. Based upon the values calculated by the NIST software, sufficient loss appears to be available in urban settings to prevent the saturation of MSS receivers in these environments.

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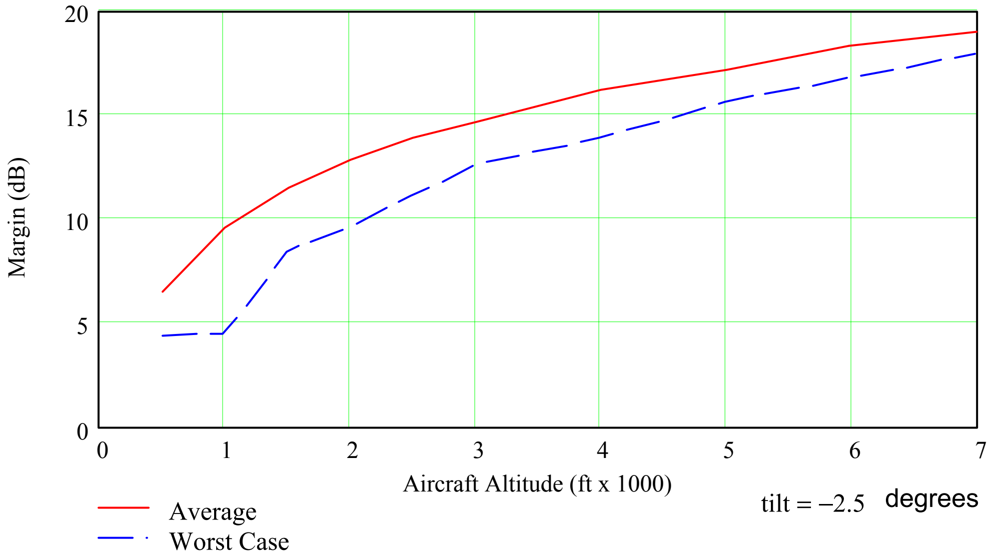
[31] *See* National Institute of Standards and Technology, Wireless Communications Technology Group, *General Purpose Calculator for Outdoor Propagation Loss*, *available at* <http://w3.antd.nist.gov/wctg/manet/prd_propcalc.html> (last visited, Jan. 30, 2003) (offering propagation software).

[32] In Tables 2.2.4.2.A and 2.2.4.2.B the free space loss is the sum of the path loss and the isotropic antenna area.

2.2.4.3 Potential Saturation of Airborne 2 GHz receivers

A potential problem discussed by the parties at L-band is the possibility of the saturation of an airborne MSS receiver from multiple BS transmitters. This same problem could potentially occur at 2 GHz between the Boeing MSS and the ICO BSs because the Boeing MSS receivers, like the L-band Inmarsat receivers, are utilized on board aircraft. A MathCad model was written to analyze this situation. The model is included as Attachment 1 to this Appendix. The model randomly distributes a number of base stations across the area visible to an aircraft at a given height. The base stations, assumed to be on thirty-meter towers, use antennas with mainbeam patterns based upon Recommendation ITU-R F.1336. The antenna roll-off is continued to 25 dB down from the mainbeam gain to represent the antennas that ICO has stated it will use. The mainbeam EIRP of each BS is 27 dBW. The MSS receiver is conservatively assumed to have a gain of 0 dBi toward all of the BSs. The total cumulative power received at the MSS terminal is calculated based upon the random distribution of a population of 1000 BS transmitters. This total received power is compared with Boeing's -50 dBm saturation level and the difference between the total received power and the saturation level is used to calculate a saturation margin. If the margin is positive, the MSS receiver is receiving an interfering signal power level insufficient to cause saturation. The program runs 100 trials of 1000 randomly placed BS and plots both the average margin over the 100 trials and the single worst case margin. Figure 2.2.4.3.A shows the average and worst case margins as a function of the aircraft altitude for a BS tilt angle of -2.5 degrees.

Figure 2.2.4.3.A Modeled Average and Worst Case Saturation Margin for Boeing Airborne MSS Terminal



As presented in Figure 2.2.4.3.A the worst case margin, shown as a dashed line, is always positive indicating that the Boeing MSS receiver would not saturate. The results of this analysis indicate that a relatively large deployment of ATC base stations would not cause Boeing's airborne MSS receivers to saturate while airborne and the potential for this type of interference is low.

3.0 Inter-Service (Adjacent Allocation) Interference Analyses

The 2 GHz Report and Order adopted service rules to protect services in the frequency bands adjacent to the 2 MSS bands from MSS operations. The following examines the effect of the addition of MSS ATC MT and BS transmitters in the MSS bands upon services in the adjacent allocations.

3.1 Analysis of Bands Adjacent to MSS Uplink Band (1990-2025 MHz)

Lower Adjacent Band (1710-1990 MHz). The frequency band 1710-1990 MHz is adjacent to the MSS uplink band. This band was auctioned for use by Broadband PCS systems. The out-of-band emission limits that ICO proposed to meet are those of a PCS system (i.e., Part 24.238), specifically -67.0 dBW/4 kHz.[33] CTIA[34] and certain incumbent PCS licensees and PCS equipment manufacturers have raised the issue of possible out-of-band emissions interference from 2 GHz ATC MTs into PCS mobile receivers operating in the 1930-1990 MHz band, which might not be adequately protected against by adopting our current limitations for PCS mobile transmitters.[35] CTIA suggests that this potential for interference could be mitigated by providing 15-20 MHz of frequency separation between the PCS bands and ATC operations. While we agree with CTIA that this potential for interference exists, we find that amount of frequency separation required between ATC mobile terminals operating under the proposed ATC limits and existing PCS mobile terminals would render unusable a significant portion of the frequency above 1990 MHz, and thus would be inadvisable. The compliance with a more stringent out-of-band emissions limitation, coupled with reallocation of the 1990-2000 MHz band to other uses, would mitigate the potential for interference while maintaining the usefulness of spectrum immediately adjacent to the 1930-1990 MHz PCS band. The 1980-2010 MHz band has been allocated for MSS use since the 1992 World Administrative Radio Conference. Since at least 1994, we have been aware of the potential for some level of interference between MSS and PCS systems.[36] PCS carriers similarly were aware of potential interference from MSS systems in adjacent spectrum, and could have taken this into account in the design of their equipment. But the likelihood of potential interference from future MSS operations was generally considered minimal due to the fact that MSS systems were expected to operate primarily in rural and/or remote environments, and in such areas the probability of an MSS handset operating close enough to a PCS handset to cause interference was low. However, ATC may pose a greater interference problem for adjacent PCS operations because of the likelihood that ATC handsets will operate in the identical environments in which PCS handset operate (e.g., in urban areas, indoors, etc.), and that in such environments ATC handsets could be close enough to PCS handsets to cause interference. Therefore, some additional requirements on ATC handsets may be necessary.

Certain incumbent wireless carriers assert that there exists the potential for ATC mobile terminals to cause desensitization or receiver overload to PCS mobile receivers operating below 1990 MHz.[37] We do not believe that the problem of desensitization and overload is as severe as these parties contend. First,

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[33] *See* ICO April 10, 2002 *Ex Parte* Letter at 2.

[34] Letter from Dianne Cornell, Counsel, Cellular Telecommunications and Internet Association to Marlene H. Dortch, Secretary, Federal Communications Commission, IB Docket No. 01-185 at 2-7 (filed Jan. 15, 2003).

[35] *See* 47 C.F.R. § 24.238(a).

[36] *See Amendment of the Commission's Rules to Establish New Personal Communications Services*, Third Memorandum Opinion and Order, 9 FCC Rcd 6908, 6922-23, ¶¶ 83-87 (1994).

[37] *See* CTIA Jan.14, 2003 *Ex Parte* Letter at 5-6.

we believe that the parties may have assumed that the only interference rejection capability of an existing PCS mobile receiver is from the front-end band pass filter of the receiver. This does not take into account other factors such as additional filtering from the intermediate frequency (IF) circuitry. Additionally, the parties' assertions that receiver desensitization or overload interference will occur appear to be based on what would be considered worst-case circumstances (e.g., that ATC and PCS handsets are operating in close proximity under line-of-sight conditions, that ATC handsets are operating at full power, and that the antennas of the handsets are aligned for perfect coupling). The probability of these various circumstances occurring simultaneously is relatively small. We thus believe that, while the potential for PCS receiver desensitization or overload from ATC operations exists, it is less than suggested by the commenting parties. We also believe that interference problems that may develop over time as ATC is deployed can be mitigated by future PCS handset design modifications and through a cooperative effort by PCS and MSS ATC licensees to resolve these issues.[38]

Upper Adjacent Band (2025-2110 MHz). The frequency band directly adjacent to the upper portion of the MSS uplink band (2025-2110 MHz) is occupied by Broadcast Auxiliary and Electronic News Gathering (BAS/ENG) services. Additionally, it is used by NASA for Earth-to-space transmissions in the space operations service. The Society of Broadcast Engineers (SBE) in its comments expressed a number of concerns including:[39]

(1) ATC might provide interference to urban TV BAS systems; in particular, the ATC base station transmitter operating in the ICO Uplink Hybrid or Reverse Band Mode could cause saturation of the receive-only ENG sites;
(2) The two ICO ATC duplex modes might be infeasible because of the stringent duplexer requirements; and
(3) ICO's ATC link budgets might contain errors, based upon SBE's conjecture that the ICO user terminal would use a single antenna for both the satellite and ATC links.

The SBE stated that "Filling that reallocated spectrum with low power, mobile MSS telephones will pose little or no risk of brute force overload (BFO) to 2 GHz TV BAS receivers."[40] But, SBE adds, "if terrestrial [ATC] cell sites will be allowed . . . . [T]he Commission would be placing high powered stations with EIRPs of up to 1,610 watts, or 62.1 dBm, immediately adjacent to systems with receiver sensitivities of around -87 dBm." And "[a]n MSS terrestrial station should not be allowed where it would result in a receive carrier level (RCL) in excess of -30 dBm" because of possible BFO of the ENG receiver.[41] Even if the power (*i.e.*, EIRP) of the ATC base station is 501 Watts (27 dBW) as mentioned in

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[38] We note that, as a practical matter, there will be some period of time before ATC is deployed and a longer period before it has the potential to reach market penetration levels that could materially affect the likelihood of interference. We also note that the Spectrum Policy Task Force report encourages the use of voluntary receiver performance requirements to address these types of problems. *See* Spectrum Policy Task Force Report at 31.

[39] SBE Comments at 16-17.

[40] SBE refers to "brute force overload." This term and "receiver saturation" are used to mean the same thing in this Appendix.

[41] SBE Comments at 20.

the ICO proposal,[42] SBE indicated that the separation distance between the ATC base station and the ENG receiver would have to be 2.6 km, assuming mainbeam-to-mainbeam coupling."[43]

The SBE calculations dealing with the pointable ENG antennas are correct. While the ICO ATC proposal did evaluate lower powered 27 dBW EIRP base stations, these transmitters could cause interference to the receive-only ENG installations. For this reason it would be necessary for ATC BS transmitters operating near the 1990 MHz band to be coordinated with existing ENG systems.

SBE also claims that in both of the ICO duplexed modes, the frequency separation between the ATC transmit and receive channels only can be, at most, 35 MHz (*i.e.*, the width of the 2 GHz MSS allocation). SBE bases its argument on the 18 MHz bandwidth of the phase I - 2 GHz MSS spectrum and not the entire allocation. SBE indicates that at 890 MHz, the frequency separation between the two sides of the PCS link is 45 MHz or (45/890*100 =) 5.0%, while at 2 GHz the frequency separation will be only (35/1990*100 =) 1.8%. ICO responded to the SBE comments on duplexers by pointing out that technology has progressed to the point where ICO estimates that only 15 to 20 MHz is currently required at 2 GHz.[44] The example that ICO quotes is the European E-TAC system, an analog, first generation, PCS system, that uses a frequency separation of (12/890*100 =1.3%). This would be equivalent to 27 MHz separation at 2 GHz.

The final SBE comment assumed that ICO would use a single antenna on the user terminal for both the satellite and ATC operations. ICO indicated that it would be using separate antennas for the ATC mode and MSS mode in its handset.[45]

Space Operations Service (2025-2110 MHz). The ITU has approved several Recommendations dealing with the Space Operations service. Recommendation ITU-R SA.1154 "Provisions To Protect The Space Research (SR), Space Operations (SO) and Earth-Exploration Satellite Services (EES) and to Facilitate Sharing With The Mobile Service in the 2025-2110 MHz and 2200-2290 MHz Bands" provides detailed information on the characteristics of the space systems and contains a study of the potential interference from 3G systems to satellite receivers. While, this study is directed at co-frequency band sharing, it can also be used to evaluate the ATC out-of-channel situation. Table 2 of Annex 1 of the Recommendation contains a number of columns, each of which calculates the interference margin from a different type of mobile transmitter. Column 1, for example, starts with a 3G user terminal that transmits –72.2 dBW/Hz and concludes that all of the mobile terminals in view of a 250 km altitude satellite will produce an interference level 16.0 dB above the selected interference criteria. Using the Commission's Part 24 emission roll-off, the ATC out-of-channel emission is –67.0 dBW/4kHz, or -103.0 dBW/Hz. Assuming the same conservative assumptions that are inherent in Recommendation ITU-R SA.1154, the ATC MTs would produce an interference margin of (16.0-(103.0-72.2) =) -14.8 dB. This is a received interference power level that is 14.8 dB below the interference criteria.

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[42] *See* ICO Mar. 8, 2001 *Ex Parte* Letter, App. B at 11.

[43] The SBE also quotes fixed sites with 45 dBi antennas (this requires an approximately 11 meter, or 38 foot, diameter antenna at 1990 MHz). The beam-width of this antenna would be about 0.9 degrees which is actually smaller than is normally used in designing fixed microwave links. This system will not be analyzed.

[44] ICO Reply, App. C at 2.

[45] ICO Reply, App. C at 3.

With respect to base stations, the fifth column of the Table contained in Recommendation ITU-R SA.1154 analyzes 3G base stations that emit –44.0 dBW/Hz and concludes that they will produce an interference level 34.6 dB above the protection criteria. The ATC base station out-of-channel emission provided by ICO, using Part 24 rules, is –67.0 dBW/4 kHz, or –103.0 dBW/Hz. This is 59 dB below the power level assumed in the Table and therefore 24 dB below the stated protection criteria. This calculation does not take into account the 25 dB suppressed upward antenna gain component that ICO indicates it will use and it assumes that there are 2.4 million active base stations in view of the low-orbit satellite. There should be no interference experienced by the adjacent band space operation systems according to our assessment.

3.2 Analysis of Bands Adjacent to MSS Downlink Band (2165-2200 MHz)

Analysis of Lower Adjacent Band (2110 - 2165 MHz). At the 1992 World Administrative Radiocommunication Conference (WARC-92), the 2110-2200 MHz band was identified for use by countries to implement future public land mobile telecommunication systems, i.e., 3G systems.[46] WARC-92 noted, however, that such use does not preclude the use of these bands for other allocated uses. The FCC has since identified the 2110-2200 MHz band, including the band immediately adjacent to the lower edge of the MSS downlink, for reallocation from the fixed service for new emerging technologies. Portions of this band, i.e., 2165-2200 MHz, have been licensed to MSS systems. If the remaining band below 2165 MHz is assigned to 3G systems then the MSS ATC assignment will be adjacent to other commercial 3G systems. In this event there should be no harmful interference between the systems. The current occupants of the 2110-2165 MHz band include both digital and analog fixed systems. These systems are described in the TIA publication, TSB 86 "Criteria and Methodology to Assess Interference between Systems in the Fixed Service and the Mobile-Satellite Service in the Band 2165-2200 MHz". The following table, Table 3.2.A, analyzes the ICO maximum out-of-band values listed in Table 1.1.B to determine the potential for impact to analog systems operating below 2165 MHz.

The fixed service utilizes two interference criteria, typically, a long term interference criteria of 20 pW0p[47] per hop that should not be exceeded for more than 20% of the time and a higher level, short term interference criteria that should not be exceeded for a very short percentage of time.[48] Table 3.2.A presents an interference link budget for the transmitters mentioned in the ICO *ex parte*. The model represented by this Table places the ATC BS and MT transmitters 20 feet from the fixed system receive antenna and in the main-beam of the receive antenna. While this is a physical impossibility for a fixed system mounted on a tower, it serves as a very conservative worst case situation. For the two ICO transmitters, the smallest margin with respect to the fixed service "long term interference criteria" is greater than 18 dB. This occurs for the ICO ATC BS transmitter. The largest margin, 37.8 dB, occurs for the ATC MT transmitter. Since the short term interference criteria are significantly higher than the long term criteria, the interference margin will be higher when dealing with short term interference.

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[46] *See Spectrum Study of the 2500-2690 MHz Band: The Potential for Accommodating Third Generation Mobile Systems*, Interim Report, 9 (rel., Nov. 15, 2000), *available at* <http://www.fcc.gov/3G/3G_interim_report.pdf> (last visited, Feb. 4, 2003) (*Interim Report on the Spectrum Study of the 2500-2690 MHz Band*).

[47] The term "pW0p" stands for psophometrically weighted picoWatts – a measurement that relates to frequency division multiplexed (FDM) voice circuits.

[48] *See* TIA Telecommunications Bulletin TSB 86, *Criteria and Methodology to Assess Interference Between Systems in the Fixed Service and the Mobile-Satellite Service in the Band 2165-2200 MHz*, § 3.2.1.

In addition to analog fixed systems, this frequency band also contains digital point-to-point systems. According to TIA "[n]o specific numerical interference criteria have been developed in either the TIA or the ITU-R to specifically address short term interference into digital receivers."[49] Because of the large interference margins calculated for analog systems, the ATC out-of-band emission should pose no unacceptable interference to either the analog or digital fixed systems operating below 2165 MHz.

Table 3.2.A – Analysis of Potential Interference to Analog Systems below 2165 MHz

Parameter	Units	Base Station	Mobile Terminals
Frequency	(GHz)	2.165	2.165
Range	(ft)	20	20
ATC Transmitter Power	(dBW/4kHz)	-100.6	-119.6
ATC Antenna Discrimination	(dB)	0.0	0.0
Polarization Loss	(dB)	0.0	0.0
Free Space Loss	(dB/m^2)	-26.7	-26.7
Receive Antenna Mainbeam Gain	(dBi)	32.2	32.2
Area of Isotropic Antenna	(dBm^2)	-28.2	-28.2
Received Power	(dBW/4kHz)	-123.2	-142.2
Psophometer Weighting Factor[50]	(dB)	2.5	2.5
Received Power	(dB(pW0W/4kHz)	-125.7	-144.7
Power Ratio dB(W/pW)	(dB)	120.0	120.0
Received Power dB(pW0p)	(dB(pW0p))	-5.7	-24.7
Long Term Criteria[51]	(pW0p)	20.0	20.0
Long Term Criteria	(dB(pW0p))	13.0	13.0
Long Term Margin	(dB)	18.8	37.8

Analysis of Upper Adjacent Band (2200 – 2290 MHz). Of the four ATC Modes considered in the ICO proposal, the Downlink Hybrid and Forward Band Mode would place BS adjacent to the 2200-2290 MHz band, while the Downlink Hybrid and Reverse Band Modes would place MTs adjacent to the 2200-2290 MHz band. The band 2200-2290 MHz is used by the United States Government for satellite-to-earth communications. Typical space research receivers use large tracking antennas located on controlled government facilities. However other installations such as universities and private companies may also make use of space research or space operations receivers under certain conditions. Recommendation ITU-R SA.1154 contains interference criteria for both space operations and space research systems that utilize the 2200-2290 MHz band as shown in Table 3.2.B.

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[49] *Id.* at 19.

[50] Bell Telephone Laboratories, Inc., *Transmission Systems for Communications*, 175 (4th ed. rev., 1971).

[51] TIA Telecommunications Bulletin TSB 86, *Criteria and Methodology to Assess Interference Between Systems in the Fixed Service and the Mobile-Satellite Service in the Band 2165-2200 MHz*, § 3.2.1.

Table 3.2.B Interference Protection Parameters for Space Research and Space Operation Services

Parameter	Units	Space Operations	Space Research
Minimum Elevation Angle	(Degrees)	3.0	5.0
Maximum Interference Level	(dBW)	-184.0	-216.0
Reference Bandwidth	(Hz)	1000	1
Assumed Antenna Gain[52]	(dBi)	20.1	14.5
Bandwidth Conversion	(dB)	30.0	0.0
Normalized Interference Limit	(dBW/Hz)	-234.1	-230.5

Also presented in Table 3.2.B is a comparison of the interference limits for the space research and space operations services. The final two rows of Table 3.2.B contains the normalized interference limit for both the space operations and space research services. This is the power level in the vicinity of the space research or space operations antenna required to equal the maximum interference level at the antenna output, taking into account the elevation angle of the antenna. As is evident from Table 3.2.B, the space operations service has the more stringent interference criteria of –234.1 dBW/Hz associated with a higher gain antenna and lower antenna elevation angles. This is the criteria that we evaluate.

Table 3.2.C presents a calculation of the interference margin for out-of-band emissions of the ICO transmitters as received by space operations receivers. The space operations downlink receive antenna is assumed to be pointed in the direction of the ATC transmitter but elevated the appropriate amount above the horizon and the ATC transmitter.

Table 3.2.C – Interference Analysis to Space Research Earth Stations

SR/SO Earth Stations	Units	ATC BS	ATC AT
Frequency	(GHz)	2.2	2.2
Range	(km)	0.82	0.09
ATC Transmitter Out-of-Band Power	(dBW/4kHz)	-100.6	-119.6
Bandwidth Ratio	(dB)	36.0	36.0
ATC Emission	(dBW/Hz)	-136.6	-155.6
Propagation Loss	(dB/m^2)	-97.5	-78.5
Interference Power	(dBW/Hz)	-234.1	-234.1
Normalized Interference Level	(dBW/Hz)	-234.1	-234.1
Margin	(dB)	0.0	0.0

Table 3.2.C shows that a separation distance of 820 m is required to protect the space operations receiver from an ATC BS. If the ATC system is limited to the Forward Link mode of operations there would be no MTs adjacent to the 2200-2290 MHz band. The BS would have to be within 0.82 km, or 0.5 miles, of the space operations receiver to cause interference. This distance should be within the controlled area of

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[52] The gain is calculated from G(Θ) = 32-25*log(Θ) dB, where Θ is the minimum elevation angle.

many United States Earth station facilities. If a space operations earth station is associated with a non-controlled area, the pointing direction of the earth station antenna would become important in determining whether or not interference would occur. If the antenna is pointed 10 degrees away from the mobile ATC MT, instead of the assumed 3 degrees, the antenna discrimination would increase by another 13 dB.

The operator should contact the Commission at the time of licensing for a list of Government and commercial earth stations using the 2200-2290 MHz band.

Annex 1 to Appendix C1
MathCad Program for Evaluating Potential Saturation of Airborne MSS Receivers at 2 GHz

The following is a look at an airborne receiver getting potential interference from a number of ATC base stations. The base stations are distributed randomly over the area visible to the aircraft. The airborne receiver has an omnidirectional antenna. The base station has a G2 antenna which is oriented with a angle of "tilt" to the horizon.

some necessary functions

$$\mathrm{dB}(x) := 10\cdot\log(x) \qquad \mathrm{r2d} := \frac{180}{\pi} \qquad \mathrm{d2r} := \frac{\pi}{180}$$

$$\mathrm{real}(x) := 10^{\left(\frac{x}{10}\right)}$$

$$\mathrm{freq} := \frac{(2.165 + 2.200)}{2} \qquad \mathrm{iso} := \mathrm{dB}\left[\frac{\left(\frac{0.3}{\mathrm{freq}}\right)^2}{4\cdot\pi}\right] \qquad \mathrm{iso} = -28.229$$

$$\mathrm{freq} = 2.183$$

model parameters

function atan2(x,y) returns the angle (0 to 360 degrees in radians) given x and y values

```
atan2(x, y) :=
    ans ← $\frac{\pi}{2}\cdot\mathrm{sign}(x)$  if  $y = 0$
    ans ← $\mathrm{atan}\left(\frac{x}{y}\right)$  otherwise
    ans ← $\pi + \mathrm{ans}$  if  $y < 0$
    ans ← $2\cdot\pi + \mathrm{ans}$  if  $x < 0 \wedge y > 0$
    ans
```

```
$spread\_cir(num, dist) :=$
    $i \leftarrow 0$
    while $i \le num$
        $xa \leftarrow (1.0 - rnd(2.0)) \cdot dist$
        $ya \leftarrow (1.0 - rnd(2.0)) \cdot dist$
        $da \leftarrow \sqrt{ya^2 + xa^2}$
        if $da \le dist$
            $az \leftarrow atan2(xa, ya)$
            $out_{i,0} \leftarrow az$
            $out_{i,1} \leftarrow da$
            $i \leftarrow i + 1$
    $out$
```

Function spread_cir generates random points over a circularly shaped area and returns the distance and azimuth of the point from a central point. Distance is returned in the input units of the argument 'dist'. Az is returned in radians. 'Num" is the number of required randomly located points. This function requires the 'atan2(x,y)' function. The returned array 'spread_cir' is a two column array. The first column (subcript n,0) is the azimuth. The second (subscript n,1) is the distance. The variable 'n;' is the running index.

Electrical parameters

Base station parameters

$Po := 10$ Base station power in dBW

Base Station Gain discrimination

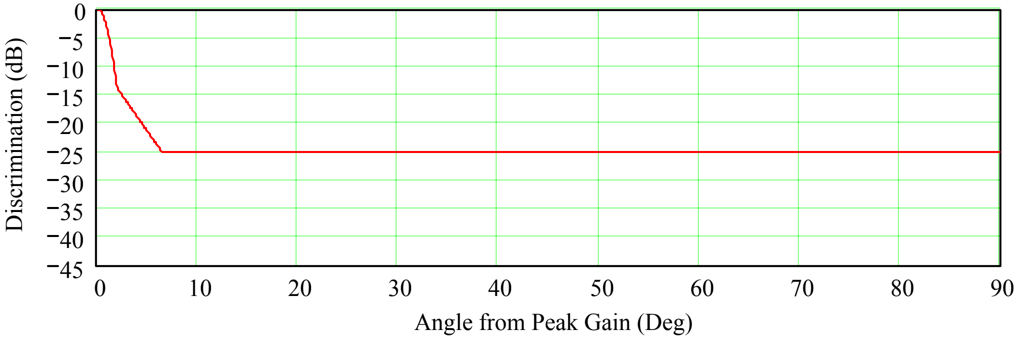
$Go := 17$ parameter used in defining antenna discrimination pattern, main beam gain = 17 dBi after ICO Application.

$\theta3 := 107.6\, 10^{(-0.1 \cdot Go)}$

```
$Gbs2(\theta) :=$
    $g \leftarrow -Go \cdot \left(\frac{|\theta|}{\theta3}\right)^2$ if $0 \le |\theta| < 1.935$
    $g \leftarrow -(|\theta| - 4) \cdot 2.5 - 19$ if $1.935 \le |\theta| < 6.4$
    $g \leftarrow -25$ otherwise
    $g$
```

Note: The antenna pattern is based on a combination of ITU-R Rec. 1336 near the mainbeam and a roll-off to a discrimination of 25 dB.

$\theta := 0..90($



$\text{tilt} := -2.5$ Tilt angle of base station antenna

$\text{EIRP} := \text{Po} + \text{Go}$ Base station mainbeam EIRP

$\text{EIRPm} := \text{EIRP} + 30$ Base station EIRP in dBm

Aircraft Gain Patterns

$\text{Gac}(\phi) := 0$ Omnidirectional constant gain from Boeing

$\text{limit} := -50$ Receiver Saturation Level in dBm from Boeing

Geometric constants and parameters

$\text{Re} := 6378 \cdot 1000$ Earth radius meters

$\text{hbs} := 30$ height of base station antenna in meters

$\text{hac\_ft} := 500$ height of aircraft in ft

$hac := \frac{hac\_ft}{5280} \cdot 1.609 \cdot 1000$ $hac = 152.367$ height of aircraft meters

$\zeta := acos\left(\frac{Re}{Re + hbs}\right)$ Central angle, base station to limb in radians

$\zeta \cdot r2d = 0.176$ degrees $\zeta \cdot \frac{Re}{1000} = 19.562$

$\xi := acos\left(\frac{Re}{Re + hac}\right)$ Central angle, aircraft to limb in radians

$\xi \cdot r2d = 0.396$ degrees $\xi \cdot \frac{Re}{1000} = 44.086$

$mdist := (\zeta + \xi) \cdot Re$

$\frac{mdist}{1000} = 63.648$ radius of area in which base stations can be seen by aircraft (km)

$\frac{mdist}{1.609 \cdot 1000} = 39.557$ miles $(\zeta + \xi) \cdot r2d = 0.572$

General model parameters

$m := 1000$ number of base station in view of aircraft

$t := 100$ number of trials of 'm' base stations

```
margin := for $j \in 0..t$                                            set loop for number of trials (t)
    $cum\_var \leftarrow 0$                                           zero out variable to cumulate answer
    for $i \in 0..m$                                                  'for loop' for number base stations in given trial
        $staloc \leftarrow spread\_cir(1, mdist)$                        place BS at random distance 'staloc'(see
                                                                              'spread_cir' function)
        $cent \leftarrow \frac{staloc_{0,1}}{Re}$                        calc. geocentric angle from a/c to staloc (rad)
        $dist \leftarrow \sqrt{(Re + hbs)^2 + (Re + hac)^2 - 2 \cdot (Re + hbs) \cdot (Re + hac) \cdot \cos(cent)}$    calc. distance from a/c to base station (m)
        $arg \leftarrow \frac{Re + hac}{dist} \cdot \sin(cent)$          calc. look angle base station ant. to a/c (rad)
                                                                           check for over flow of argument before taking
                                                                           'acos'
        $arg \leftarrow sign(arg)$ if $arg \geq 1.0$
        $bs2ac \leftarrow acos(arg)$
        $bs2ac\_tilt\_deg \leftarrow bs2ac \cdot r2d - tilt$             calc. gain discrimination of base station antenna
        $bsgaindisc \leftarrow Gbs2(|bs2ac\_tilt\_deg|)$                    towards a/c taking into account antenna tilt
        $ac2bs \leftarrow \frac{\pi}{2} - bs2ac - cent$                  calc. aircraft to base station look angle (ac2bs)
        $ac2bs\_ant \leftarrow \pi - ac2bs$                              assume a/c antenna is looking up and calc.
        $ac2bs\_ant\_deg \leftarrow ac2bs\_ant \cdot r2d$                   off-axis angle (ac2bs_ant=180-ac2bs)
        $acgain \leftarrow Gac(|ac2bs\_ant\_deg|)$                       get gain from a/c to base station (acgain)
        $ggrr \leftarrow bsgaindisc + acgain + dB\left(\frac{1}{4 \cdot \pi \cdot dist^2}\right)$    bts to a/c gain disc x ac to bs gain x spreading
                                                                             loss (in dBs)
        $cum\_var \leftarrow cum\_var + real(ggrr)$                      cumulate gains x loss as real values
    $cum_j \leftarrow -(dB(cum\_var) + iso + EIRPm - limit)$          finished 'for loop' - convert real to dB and add
cum                                                                   isotropic antenna area, EIRP (in dBm) and subtract
                                                                      'limit' to get difference between received power for
                                                                      m stations in view of aircraft and the saturation
                                                                      limit.  A positive value implies received power is
                                                                      less than limit, i.e., a positive margin.
```

$$ave := dB\left(\frac{1}{t+1}\cdot\sum_{i=0}^{t} real\left(margin_i\right)\right)$$

'ave' is the average expected coupling loss between all of the base stations and the aircraft receiver. The aircraft gain, path loss and transmitter discrimination summed across all of the base stations are accounted for. The min and max are the highest and lowest values across all of the trials. Adding the transmit EIRP and other non-geometrically based gains and losses will yield the power received by the aircraft receiver.

$ave = 6.594$

$min(margin) = -0.166$

$max(margin) = 7.423$

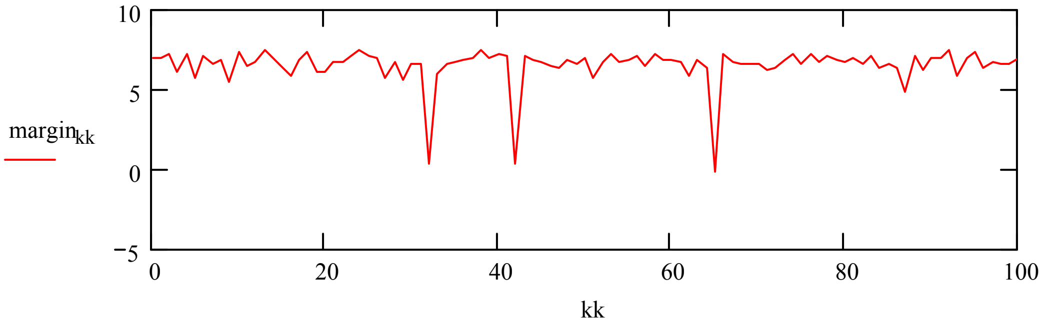
$m = 1 \times 10^3$

$hac = 152.367$

$t = 100$

$hbs = 30$

$kk := 0..t$



margin =

	0
0	6.956
1	6.887
2	7.152
3	6.124
4	7.239
5	5.706
6	7.08
7	6.532
8	6.846
9	5.438
10	7.27
11	6.394
12	6.73
13	7.423
14	6.9

This plot examines the change in isolation between the aircraft and the base station as a function of the aircraft altitude.

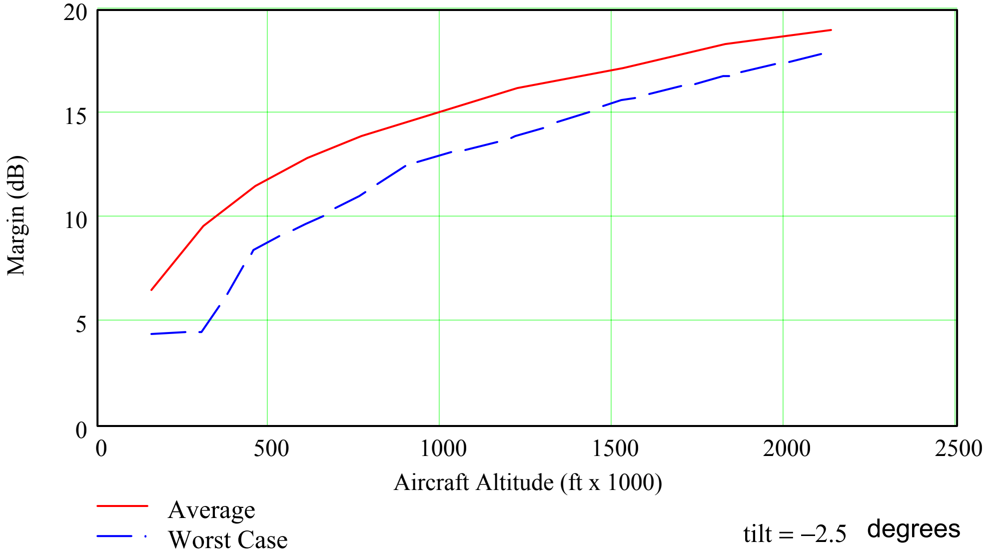
$$\mathrm{hei} := \begin{pmatrix} 152.4 & 6.5 & 4.41 \\ 304.7 & 9.54 & 4.45 \\ 457.1 & 11.5 & 8.5 \\ 609.5 & 12.87 & 9.7 \\ 761.8 & 13.85 & 11.09 \\ 914.2 & 14.7 & 12.6 \\ 1219 & 16.19 & 13.91 \\ 1524 & 17.2 & 15.61 \\ 1821 & 18.28 & 16.74 \\ 2133 & 19.01 & 17.89 \end{pmatrix}$$

$k := 0..9$

Tilt Angle -2.5 Degrees

$$\mathrm{hei}_{k,0} := \frac{\mathrm{hei}_{k,0}}{1000} \cdot \frac{1}{1.609} \cdot \frac{5280}{1000}$$

convert altitude to (ft x 1000)



$\mathrm{tilt} = -2.5$ degrees

APPENDIX C2 -- TECHNICAL EVALUATION OF L-BAND ATC PROPOSALS

Inmarsat has stated in response to the *Flexibility Notice* that granting MSV a license to use its proposed ATC system would lead to a number of interference situations with respect to the currently operating and future generation Inmarsat systems. In presenting its case, Inmarsat made a number of assumptions in calculating interference from both the ATC mobile earth terminals (ATC MTs) and ATC base stations. MSV analyzed Inmarsat's claims of potential interference, made certain other assumptions in its calculations, and came to more promising conclusions on the potential for interference to Inmarsat's networks. Below, we analyze the assumptions used in the competing analyses (Section 1, Assumptions), provide an individual assessment of the potential for interference from MSV's ATC operations to Inmarsat's networks (Section 2, Intra-Service Sharing) including land-based MSS receivers and receivers operating in the AMS(R)S and GDMSS services, and we evaluate the potential for interference that may be caused to other radiocommunication systems operating in frequency bands adjacent to MSV's proposed ATC system (Section 3, Inter-Service Sharing).

1.0 Assumptions Used in Analyses of Potential Interference

The following is an assessment of the assumptions used in the competing analyses contained in the record.

1.1 Polarization Isolation

Polarization mismatch loss is the ratio at the receiving point between received power in the expected polarization and received power in a polarization orthogonal to it from a wave transmitted with a different polarization. The polarization of an antenna remains relatively constant throughout the main lobe of the antenna pattern, but can vary considerably outside the mainlobe. In practice, polarization of the radiated energy varies with direction from the center of the antenna such that different parts of the antenna pattern and different sidelobes have different polarizations. When the locations of the transmitting and receiving stations are generally known and the analysis is considering mainbeam or near mainbeam antenna coupling, a polarization mismatch loss is included in the analysis.

Inmarsat references a value of 1.4 dB for polarization isolation for all cases of linear to circular, non-identical polarization mismatch between an MSV transmitter and an Inmarsat satellite receiver.[53] MSV argues that when an ensemble of randomly oriented linearly polarized emitters is received by a circularly polarized receiver, an isolation value of 3 dB should be used.[54] Because the orientations of the linear transmit ATC antennas will not be truly random[55] we take the more conservative 1.4 dB number proposed by Inmarsat into account in our analyses.

Regarding orthogonal circular polarization, MSV states that a value of 8 dB would be appropriate for a near-off-axis circular polarized transmitter being received by an orthogonal circularly

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[53] Inmarsat Comments at 27.

[54] MSV Reply at 8.

[55] It is expected that the ATC handset antennas will be oriented in some distribution about the local vertical and, therefore, will not have an equal probability of being oriented in all directions.

polarized receiver.[56] MSV has submitted both analytic and measured information in support of this claim.[57] The measurements provided by MSV cover the angular range from near-bore-sight to about 30 to 40 degrees off bore-sight for an Inmarsat Mini-M antenna. Therefore, our analysis uses 8 dB as the polarization isolation factor for, near boresite, orthogonal circular polarization cases. MSV proposes that the ATC base stations will employ LHCP. Other values of polarization isolation may be used in special situations, and an explanation is provided where the situation warrants a different number.

1.2 Signal Blockage in Urban Environment

In their comments and *ex parte* presentations, Inmarsat and MSV have used different values for signal blockage in their analyses of the potential for ATC MT interference to Inmarsat's satellites. MSV used a value of 15.5 dB, which is a value that is supported by Dr. Wolfhard J. Vogel, who is an expert on L-band propagation.[58] In one of its *ex parte* comments, MSV proposed to reduce this value to 10 dB to be more conservative than the 15.5 dB originally used in its analyses.[59] Inmarsat, however, refers to the "Handbook of Propagation Effects for Vehicular and Personal Mobile Satellite Systems,"[60] and contends that the Handbook supports a "typical" blockage of only about 2 dB.

This "blockage" factor is the average attenuation or loss of signal strength between an ATC MT and a satellite receiver. Since the ATC system is proposed to be deployed in urban environments, it is expected that there will be some loss caused by structures such as buildings and trees between the ATC MTs and the satellite receivers. The debate on the value of the blockage factor revolves around the average loss that would result from a large number of ATC MTs. For the Inmarsat system, the blockage factor is important because it determines to what extent the ATC MT transmitter signals will increase its noise floor due to this potential interference environment. MSV has stated that it will limit its intra-system interference (self-noise from its own ATC system) to an increase in noise of 0.25 dB.[61] By setting its intra-system interference objective, MSV calculates the number of ATC MTs its system can support without receiving self-interference. This calculation is dependent upon the assumed "blockage" factor between the MTs and the MSV satellite. Therefore, the assumed blockage between the MTs and the satellite receiver is important to both parties.

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[56] MSV Reply, Technical App. at 24.

[57] *See* MSV May 1, 2002 *Ex Parte* Letter at 2-8.

[58] MSV Reply, Technical App. at 1-2 (incorporating statement by Dr. Wolfhard Vogel).

[59] MSV Jan. 10, 2002 *Ex Parte* Letter at 21.

[60] Julius Goldhirsh & Wolfhard Vogel, *Handbook of Propagation Effects for Vehicular and Personal Mobile Satellite Systems*, (Dec. 1998), *available at* <http://www.utexas.edu/research/mopro/> (last visited, Feb. 1, 2003).

[61] MSV Jan. 10, 2002 *Ex Parte* Letter at 4.

1.2.1 MSV's Proposed Blockage Factor

The value of 15.5 dB of blockage originally proposed by MSV was based upon an assumed distribution of ATC MT users. Specifically, the study by Dr. Vogel assumes that "outdoor"[62] users would have a blockage factor of 13.8 dB, users in buildings would have a blockage of 18 dB and users in vehicles would have a blockage of 21.3 dB.[63] The study also distributes the user population according to the following in Table 1.2.1.A.

Table 1.2.1.A: Distribution of ATC MTs and Associated Blockage Factor

User Location	Users (%)	Blockage (dB)
Outdoors	30	-13.8
In Vehicles	30	-21.3
In Buildings	40	-18.0
Average Loss		-16.8

This user distribution results in an average blockage factor of 16.8 dB. Based upon this calculation, MSV contends that its blockage factor of 10 dB is conservative. In addition, the study by Dr. Vogel indicated that, for a handheld MT, the user also blocks the signal by an additional 3 dB due to Radio Frequency (RF) absorption by the human head and body.[64] This "body blockage" was accounted for in the typical blockage factors listed in Table 1.2.1.A.

1.2.2 Inmarsat's Proposed Blockage Factor

Inmarsat refers in its Comments and *ex parte* presentations to the "Handbook of Propagation Effects for Vehicular and Personal Mobile Satellite Systems" which was authored in part by Dr. Vogel. Inmarsat contends that the Handbook supports an "average blockage" of only 1.9 dB.[65] Specifically, the figure used in Inmarsat's *ex parte* presentation is reproduced below as Figure 1.2.2.A (Figure 10-4 from the Handbook). The left hand portion of Figure 1.2.2.A shows the probability that a specific user-to-satellite loss will occur according to a number of different blockage models. As can be seen in the figure, the fiftieth percentile loss is about 3 dB. This would indicate that 50% of the users would experience a loss greater the 3 dB and 50% less than 3 dB. Since this figure is for a satellite seen at an elevation of 32 degrees, the average (50th percentile) loss due to urban blockage can be taken as 3 dB as opposed to Inmarsat's 1.9 dB

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[62] If the user is on the street in an urban setting, buildings and other structures would attenuate the ATC MT signals.

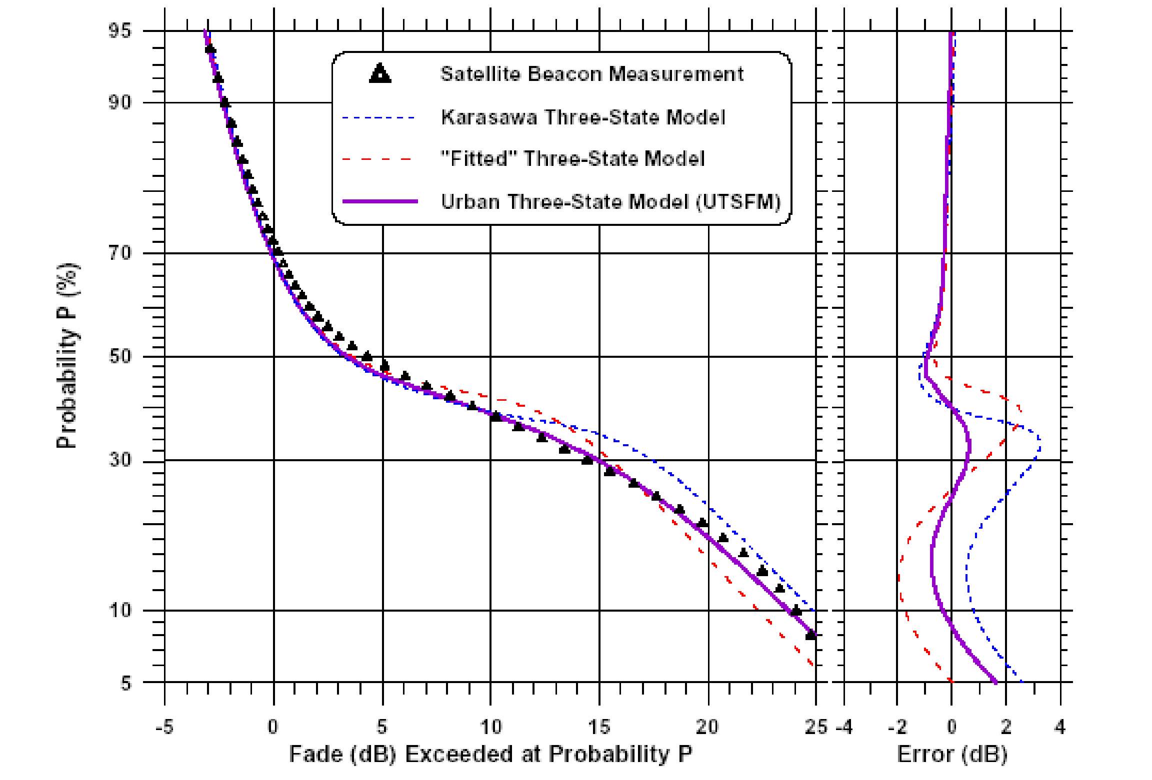
[63] The 21.3 dB is composed of two parts: 7.5 dB from being inside the vehicle and an additional 13.8 dB from being outdoors on the street in an urban setting.

[64] *See* Toftgaard, J., IEEE Transactions on Antennas and Propagation, *Effects on Portable Antennas of the Presence of a Person*, Vol. 41, No. 6, (June 1993). Measurements were carried out on GSM and DECT handheld cellular phones, at 900 MHz and 1800 MHz. Between 45% and 55% of the transmitted power was absorbed by the head and body or the cell phone user, yielding a loss of signal due to 'body blockage' of between 2.6 and 3.5 dB.

[65] To put the blockage values (given in dB) into context, a blockage value of 15 dB corresponds to a signal reduction between the ATC MT and the Inmarsat satellite by a factor of more than 30; MSV's blockage value of 10 dB corresponds to a signal reduction by a factor of 10; and Inmarsat's blockage value of 1.9 dB corresponds to a signal reduction of only 1.5.

value. Inmarsat assumes that all ATC users will be located outdoors and no additional attenuation from operations inside vehicles or inside buildings is taken into account.

Figure 1.2.2.A: Handbook Figure 10-4



In the Handbook discussion, the elevation angle from the MT to the satellite receiver is a very important parameter in determining attenuation due to blockage. This parameter is not evaluated by Inmarsat in its analysis. The data used to produce Figure 1.2.2.A was derived by the satellite located with a 32° elevation angle with respect to the MT. Figure 1.2.2.B, below, is taken from Figure 10-5 of the Handbook. This figure represents data on the change in blockage to a satellite as the elevation angle to the satellite is varied.

Figure 1.2.2.B: Handbook Figure 10-5

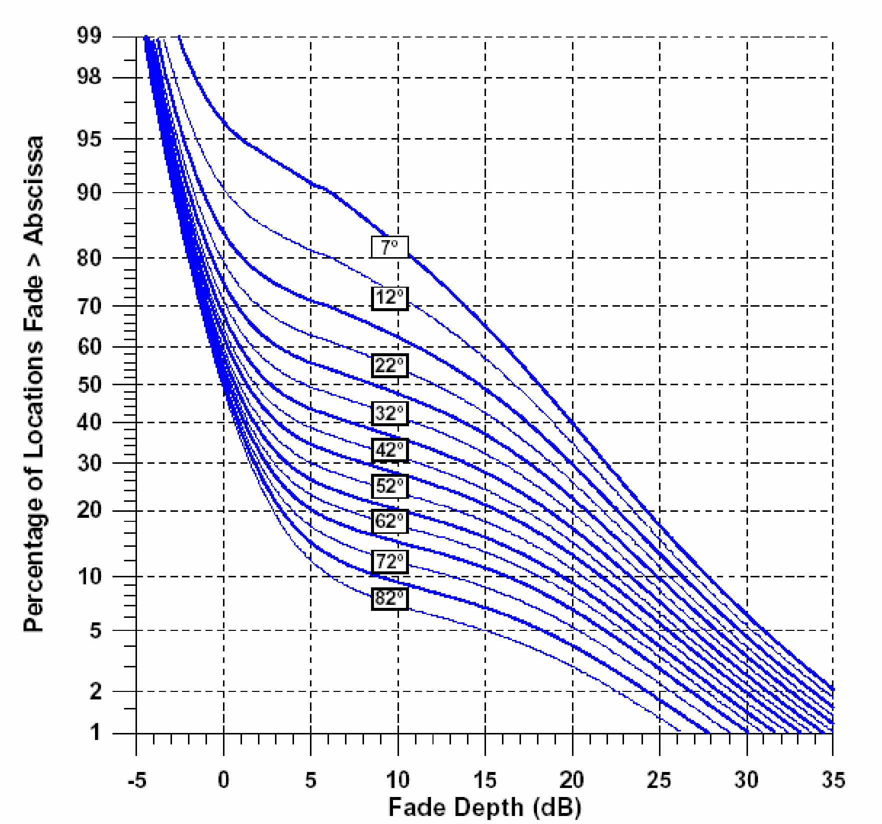


Figure 1.2.2.C shows the expected difference in attenuation, due to blockage, as a function of satellite elevation angle for the 50th percentile. The data used in Figure 1.2.2.C is directly derived from Figure 1.2.2.B. Figure 1.2.2.C indicates that the blockage factor increases significantly as the elevation angle to the satellite decreases. For example, the attenuation due to blockage would be 7.5 dB higher for a satellite seen at 22 degrees elevation when compared with one at 32 degrees. Conversely, if the elevation angle is raised by 10 degrees (from 32 to 42 degrees) the average blockage decreases by only about 3 dB. In sum, the amount of signal blockage increases very rapidly as elevation angles to the satellite decrease.

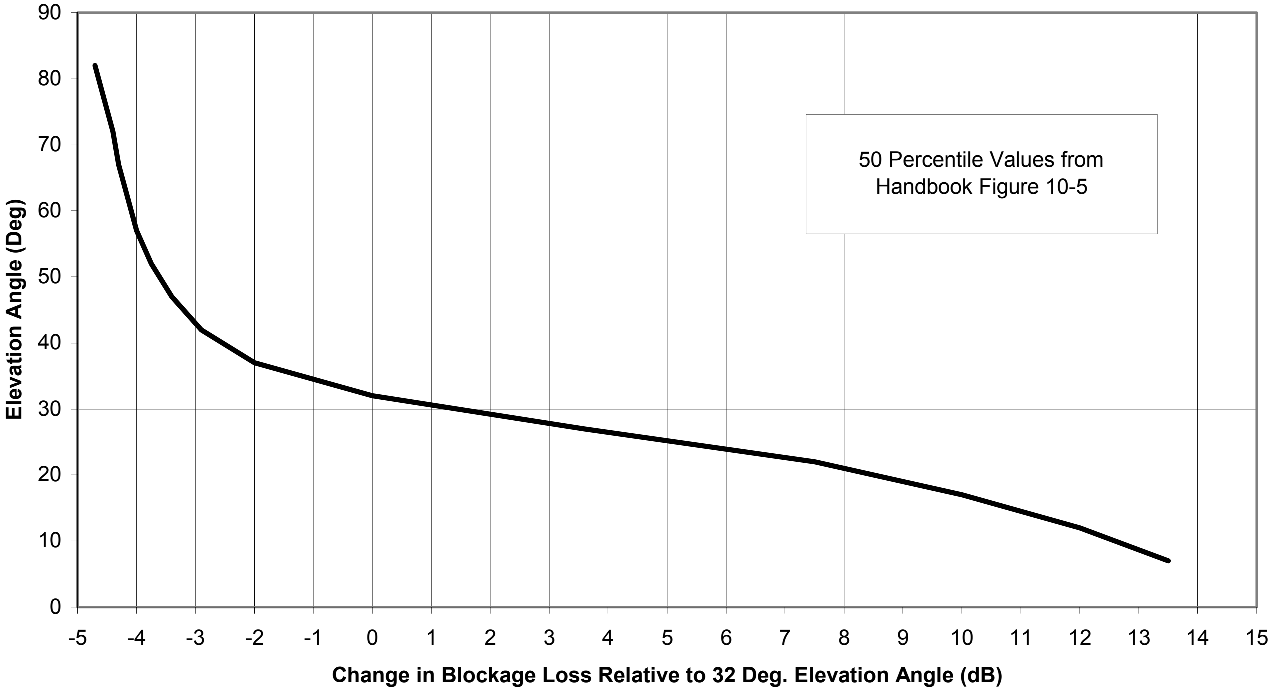


Figure 1.2.2.C: Change in Blockage with Satellite Elevation Angle (50th Percentile)

1.2.3 Analysis of Elevation Angles on Average Outdoor Blockage

Inmarsat currently operates the Atlantic Ocean Region-West (AOR-W) satellite at 54° W.L., the Atlantic Ocean Region-East (AOR-E) satellite at 15.5° W.L. and the Pacific Ocean Region (POR) satellite at 142° W.L. The average elevation of these satellites to the 48 Contiguous United States (CONUS) is relatively low.[66] MSV's satellite currently operates at the 101° W.L. orbital location. Table 1.2.3.A shows the elevation angles from a number of locations in CONUS to the MSV satellite and the various Inmarsat satellites.

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[66] Inmarsat has begun to coordinate an additional satellite at 98° W.L. but, due to the time involved, coordination has not been reached and the satellite has not been launched into that orbital location.

Table 1.2.3.A: Elevation Angles to Various Cities as seen from Operating L-band Satellites

GSO Location	Inmarsat AOR-E 15.5 W.L.	Inmarsat AOR-W 54 W.L.	Inmarsat POR 142 W.L.	MSV 101 W.L.
Washington	14.0	40.7	11.2	40.2
Boston	16.3	38.1	5.3	32.5
Miami	14.3	48.4	16.9	52.2
Dallas	-	30.6	29.0	51.9
Denver	-	20.8	30.4	43.9
Bismarck	5.1	32.3	18.0	41.5
Seattle	-	7.4	37.2	36.7
San Francisco	-	8.5	41.9	41.2
San Diego	-	14.0	43.7	48.4

Table 1.2.3.A shows that the elevation angles for the Inmarsat satellites tend to be lower than for the MSV satellites. Therefore, according to Figure 1.2.2.C, the blockage between a point in the United States and the Inmarsat satellite should be somewhat higher than the blockage between the same point and the MSV satellite. We conducted an analysis to determine the relative blockage from the approximate center of all 50 states to the various satellites. These relative blockage values were weighted by the percent of the United States population residing in each state in accordance with the 2000 Census. The average relative blockage values that were determined are shown in column three of Table 1.2.3.B. Table 1.2.3.B also presents the average blockage at 32 degrees elevation, shown in column two, which is taken from Figure 10-4 of the Handbook mentioned in the previous section. The third column shows the expected difference between the blockage of a satellite at 32 degrees elevation and the population-weighted average blockage values for the four satellites. The sum of these values, shown in column four, is an estimate of the average expected outdoor blockage to operations from the different satellites for outdoor users.

Table 1.2.3.B: Expected Average Outdoor Satellite Blockage to United States

Satellite	Avg. Blockage At 32 deg.	Avg. Blockage Rel. to 32 degree Elevation	Expected Avg. Outdoor Blockage
MSV	-3.0	+2.5	-0.5
AOR-W	-3.0	-0.1	-3.1
POR	-3.0	-3.3	-6.3
AOR-E	-3.0	-14.5	-17.5

As demonstrated in Table 1.2.3.B, because the elevation angle to the MSV satellite is higher than for the Inmarsat satellites, the blockage factor to the MSV satellite can be expected to be less than that between the same ATC MT and the Inmarsat's satellites.

1.2.4 Average Outdoor Blockage Factor Used in Analyses

The above analysis demonstrates that the currently operating Inmarsat satellites should have about 2.5 dB more outdoor blockage than the outdoor blockage to the MSV satellite. An average blockage factor of about -3 dB can be expected between an ATC MT transmission and an Inmarsat satellite, while an outdoor blockage factor of about -0.5 dB would be available to the MSV satellite.

1.3 Power Control[67]

The power control system is used within a cellular system to equalize the power received at the base station antenna and to minimize the power transmitted by both the base station and MT. This reduces both the inter- and intra-cellular interference in the system and maximizes the battery life in the MT.

Inmarsat assumes a 2 dB power control factor for the MSV MTs. MSV, however, maintains that a 6 dB power control factor would be appropriate. Inmarsat provides no rationale for its 2 dB assumption except that the actual value is expected to be dependent on the MT deployment scenario. MSV provided a deployment scenario that results in a 7.5 dB power control factor by its calculation.[68] MSV then states that closed loop power control will reduce average emissions by at least 6 dB.

MSV's argument for a 6 dB MT power control factor is based upon the fact that with a closed loop power control system the transmit power of a MT will be a function of the blockage between the MT and the base station. MSV assumes a population of ATC users distributed with some users in buildings and some outside of buildings. MSV further assumes that the ATC system will have a maximum link margin of 18 dB reserved to overcome blockage between the MT and the base station. MSV then calculates the average amount of blockage margin that is required to overcome the average blockage experienced by the MT population (10.5 dB) and contends that the power control factor will be (18-10.5 =) 7.5 dB. In other words, the average MT will represent a potential interference source (18-10.5 =) 7.5 dB below the peak MT transmit power. This rationale is used to show that a power control factor of 6 dB is conservative.

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[67] For purposes of the present discussion, we consider "power control" to be comprised exclusively of (i) range compensation (also known as "range taper"); (ii) structural attenuation; and (iii) body absorption. Although some commenters include other attenuation factors within their individual conceptions of "power control," we consider other attenuation factors, including building blockage, separately.

[68] *See* MSV Reply, Technical App. at 6-7.

1.3.1 MT to Base Station Structural Attenuation[69] Compensation[70]

With respect to base station structural attenuation, we agree with MSV's argument in general, but disagree with its conclusions. Using MSV's proposed ATC link budget, a maximum margin of 18 dB is reserved for overcoming structural attenuation that could exist between the MT and the base station. Our understanding of cellular system design is, for example, if a user standing in the open at the edge of the cell coverage area accesses the ATC system, the MT would be requested during the initial exchange of information between the user MT and the base station to reduce its power by the full 18 dB structural attenuation margin because no structural attenuation exists between the MT and base station. If that same user enters a building and stands near a window in a location which has 15 dB of structural attenuation between the MT and the base station, the ATC system would have the MT increase power by 15 dB via the closed loop power control to compensate for the structural attenuation. However, MSV indicates that the MT's power will be seen as a potential interference source at a power level (18-15 =) 3 dB below its peak power. The power actually available to cause interference in another system is the power level of the MT minus the structural attenuation factor or 18 dB below its peak power. The potential interference power, in this case, is the power radiated out of the building, not the MT transmit power.

The same holds true if the user enters an automobile that has 7 dB of structural attenuation towards the base station. The MT, in this case, would be requested to increase its power by 7 dB, from the -18 dB level required outside the automobile to (-18+7 =) the -11 dB that would be required to overcome the structural attenuation caused by the automobile. The power available to potentially cause interference would not be the -11 dB transmitted power level. It will be the MT transmit power minus the automobile structural attenuation or (-11-7 =) -18 dB.

Therefore, for users at the cell edge-of-coverage, the power control factor in the MT to base station direction will be the total margin designed into the ATC system (i.e., 18 dB as assumed by MSV) to overcome structural attenuation between the MTs and base station.

1.3.2 Base Station to MT Blockage Compensation

In the opposite direction of transmission (i.e., from the base station to the MT), the base station will increase its power to compensate for the structural attenuation between the base station and the MT. In this case, the entire transmit power of the base station can be received by another system and potentially cause interference. MSV assumes that the ATC system has a maximum structural attenuation margin of 18 dB, that all of the users are at the edge of coverage and that:

- 50% of the users are in the open in relatively clear locations having 3 dB of structural attenuation between the base station and MT; and,

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[69] By "structural attenuation" we mean the signal attenuation that takes place when an ATC MT transmits within a building, automobile or other structure that completely encloses the MT. We differentiate "structural attenuation" from "outdoor blockage." Outdoor blockage occurs where the line-of-sight propagation path between a transmitter and a satellite receiver is obscured by obstacles such as buildings or trees. Outdoor blockage is discussed in section 1.2, *supra*.

[70] This discussion of power control is adapted from a similar discussion in an Industry Canadian funded document authored by COMTEK Associates. *See* COMTEK Assoc., Inc., *Use of Mobile Satellite Spectrum to Provide Complementary Terrestrial Mobile Service to Improve Satellite Coverage,* (Nov. 2002), *available at* <http://strategis.ic.gc.ca/SSG/sf05569e.html> (last visited, Jan. 31, 2002) (*COMTEK Associates Report*).

- the other 50% of the users are located in buildings with 80% of these users being near windows and having 10 dB structural attenuation and 20% being in the building's interior and having 18 dB of structural attenuation. [71]

Under these circumstances, the base station would have to increase its power by an average of 10.5 dB, across all users, to compensate for the structural attenuation of all of the users. The base station transmit power available to potentially cause interference will be (-18+10.5 =) -7.5 dB below the base station peak power.

1.3.3 Power Control for Range Compensation

In addition to structural attenuation, the power control system compensates for the "near-far" problem. Simply put, the closer the MT is to the base station the less power is required to communicate between the two. For example, if the user initially starts at the edge of coverage of the cellular system and walks towards the base station, the power control will reduce the amount of power transmitted as the distance between the user and base station is reduced. The amount of reduction, as a function of separation distance, depends upon the propagation characteristics that occur in the cell. In open areas, the propagation loss is characterized as a function of the separation distance squared. In urban and city settings, the propagation loss can be a function of the separation distance taken to the third or fourth power.[72] The average range compensation loss is also a function of the way power control is implemented depending upon the size of the power control step and the number of power control steps. Sprint and Cingular submitted an ex parte study conducted by the Telcordia Technologies that contains an analysis of range compensation power control for a cellular system assuming a hexagonal cell packing structure.[73] The analysis assumes a path loss exponent[74] of 3.5 and concludes that this portion of the power control will result in an average power reduction factor of 6 dB. This factor would apply to both the MT and the base station.

1.3.4 Body Absorption or Body Blockage

As mentioned in Section 1.2.1, about half of the transmit power of a handheld MT is absorbed by the person operating the MT.[75] This phenomena will result in a 3 dB increase in transmit power in both the MT and base station. In the case of the MT, the power will be absorbed locally, by the user, and will not contribute to any type of interference. The resulting increase in power at the base station will radiate into space and could potentially contribute to an interference situation.

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[71] *See* MSV Reply, Technical Annex at 7.

[72] For example, the Egli Path Loss model, *see Radio Propagation Above 40 MHz Over Irregular Terrain,* Proc. IRE, Vol. 45, Oct. 1957 at 1383-91, assumes that path loss is proportional to distance raised to the fourth power. The Hata Model assumes that path loss varies as a function of transmitter length. *See* J.S. Lee & L.E. Miller, *CDMA System Engineering Handbook* (Boston: Air Tech House 1998).

[73] Sprint/Cingular Telcordia Study, Attach. A at 19-20.

[74] RF propagation loss in free space is assumed to be proportional to the distance squared (D^2). Another way of expressing this is to say that the propagation loss assumes a path loss exponent of 2. Propagation models for urban settings result in path loss exponents of between 3 and 4 depending upon the model used.

[75] *See* Toftgaard *supra* note 65.

If, as stated above, the power of the MT is absorbed locally (and therefore does not contribute to interference), and the MT is operating at or near its maximum power, only half of that power will radiate out and be capable of contributing to any interference. The peak radiated power from a 1 Watt handheld MT, therefore, will only be ½ Watt, whereby the remaining ½ Watt is absorbed by the user. By assuming that body absorption makes no contribution to a reduction in interference potentially caused by an MT, we are being conservative.

1.3.5 Summary of Power Control and Blockage

The power control system is used to compensate for a number of different factors:

- Range Compensation – which will vary from about 3 to 6 dB based upon the design of the cellular system. For example, in a cellular system based upon hexagonal cells the range compensation factor will be about 6 dB, while in a cellular system based upon circular cells will have a value of about 3 dB.[76] The actual value will also depend upon the propagation parameters assumed within the cell.

- Structural Attenuation – which can vary from about 10 to 20 dB based upon the design and purpose of the ATC cellular system. For example, the COMTEK report assumed 10 to 20 dB of structural attenuation would typically be budgeted within the system. [77] MSV asserts that, per standard PCS design practices, 18 dB of building penetration margin is allocated to the available link margin at edge of coverage.[78] A value of 10 dB appears to be typically for structural attenuation from other sources. [79]

- Body Adsorption – which must also be accounted for by the power control system and can vary from 2 to 4 dB.[80]

In proceeding with our analysis we will assume an average value power control factor of 20 dB in the MT to BS link. This factor, as explained above, applies independent of the distribution of ATC users. Our analyses is based on the expectations that MSV will implement the full 18 dB of margin for structural attenuation that they state is “per standard PCS design practices” and that they will implement the maximum dynamic range of power control contained in the GSM system specification.

In the BS-to-MT direction, the ATC user distribution used by MSV (and discussed below in section 1.2.1) consisted of 40% of users in buildings which would use the full structural attenuation, 30% of the users in vehicles and 30% of the users in the open. This distribution leads to a base station to MT power control factor of 2.2 dB as shown in Table 1.3.5.A and a total

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[76] Sprint/Cingular Telcordia Study, Attach. A, at 19-20.

[77] *See COMTEK Associates Report* at 59.

[78] MSV Reply Comments, Technical App. at 6-7.

[79] *See, e.g.,* http://150.250.105.16/~krchnave/spring2002/wireless/Kluwer_CD/chaptr04/outage/linkbudg.htm.

[80] *See* Toftgaard *supra* note 65.

power control factor of 5.2 dB. We use this value when analyzing potential interference from multiple BSs.

Table 1.3.5.A Structural Attenuation and Power Control Losses in the Base Station to MT Direction

	Inmarsat	MSV	Staff
Range Compensation	2.0	6.0	6.0
Structural Attenuation	0.0	10.0	2.2
Body Blockage	0	3.0	-3.0
Total	2.0	19.0	5.2

1.3.6 ATC Power Control Algorithms

MSV proposes to implement a TDMA GSM 800 or DSC 1800 system for ATC. The GSM standards specify wide power control range, approaching a dynamic range of 30 dB, when fully implemented.[81] Because the use of power control will be very important in reducing the potential for interference to other MSS systems, power control on both the base stations and the MTs should be implemented. The power control implemented should have the widest dynamic range as contained in system standards for both the base station and the MT. The values derived in Section 1.3.5 are used in our analyses to account for power control factors.

1.4 Out-of-Band Emissions

In assessing interference to its satellites from MSV's ATC MTs, Inmarsat assumes an out-of-band attenuation of 43+10*log(P) per 200 kHz of bandwidth. A Commission rule for a similar type of transmitter states that the out-of-band emissions must be attenuated by at least 43+10*log(P) in a 1 megahertz bandwidth (except immediately adjacent to the occupied band).[82] The difference in the measurement bandwidth would require a minimum out-of-band attenuation of –50 dB, not –43 dB as proposed by Inmarsat. A –50 dB value is used in our analyses unless MSV has specified a specific out-of-band value that is more attenuated, in which case that value is used.

1.5 Spurious Emissions

MSV uses a value of –57.9 dBW/MHz (-117.9 dBW/Hz) for spurious emission levels in calculating the potential out-of-band interference to Inmarsat's MES from its base stations. MSV states that its ATC equipment manufacturer, Ericsson, has committed to meeting this value.[83] In the analysis of potential interference to airborne Inmarsat terminals, Inmarsat used a reduction from peak power to out-of-band power of 68 dB (to –101.9 dBW/Hz, per carrier) and for a three carrier sector a total of –97.1 dBW/Hz for the base station. This provides over 20 dB more conservative attenuation between what MSV equipment manufacturer states that MSV's equipment will be capable of meeting and the value that Inmarsat used in its analysis. We will use the lower value.

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[81] *See* ETSI Standard 300 609-1 and 300 609-4.

[82] *See* 47 C.F.R. § 24.238.

[83] MSV Comments, Technical App., Ex. E at 1-8.

1.6 Path Loss in the Vicinity of the ATC Base Station

Inmarsat uses a free-space loss equation to determine the expected attenuation from the ATC base station to its mobile earth stations (MES). MSV uses the Walfisch-Ikegami (WI) propagation model which results in a greater attenuation for the same case. The WI model is based upon the expected propagation loss in an urban/city setting that consists of relatively tall buildings. The WI model is actually comprised of two different models – one for line-of sight (LOS) and a second for non-line-of sight (non-LOS) path loss. The National Institute of Standards and Technology (NIST) developed a computer program that compares a number of different propagation models including the WI model and its components. Using the NIST software,[84] propagation loss values can be calculated from the Hata-city and CCIR (now ITU-R) models in addition to the WI LOS and non-LOS models. Propagation models that produce higher than free-space losses are valid for many urban areas. However, in urban areas with large open spaces, such as airports and harbors, and possibly near navigable waterways, free-space propagation loss should be assumed. Depending upon the geographic area we analyze we use the WI (LOS and non-LOS) and free space propagation as appropriate.

1.7 Satellite/Ground Path Loss

Both MSV and Inmarsat consistently use -188.8 dB path loss from GSO to the CONUS. One standard formula for free-space loss is:

$$L=20\text{Log}_{10}(F)+20\text{Log}_{10}(D)+32.45;$$

Where: F is frequency in MHz and D is distance in km.

For the MSV satellite at 101 degrees W.L., pointing to the approximate center of the United States (latitude 38 degree North, longitude 101 West) the distance would be about 37820 km (using a GSO radius of 42644 km). For the closest existing Inmarsat satellite, at 54° West Longitude, pointing to the center CONUS the distance is about 39580 km. The nominal satellite/ground path loss for the uplink and downlink bands are shown in Table 1.7.A

Table 1.7A Values of Satellite/Ground Path Loss used in Analysis

Space System	Downlink Band	Uplink Band
Inmarsat	-188.2	-188.7
MSV	-187.8	-188.3

1.8 ATC Base Station Antenna Patterns and Achievable Isolation to Aircraft Receivers

In its analyses, Inmarsat references an antenna radiation pattern contained in Recommendation ITU-R F.1336 to demonstrate what it believes to be as the best isolation that should be expected

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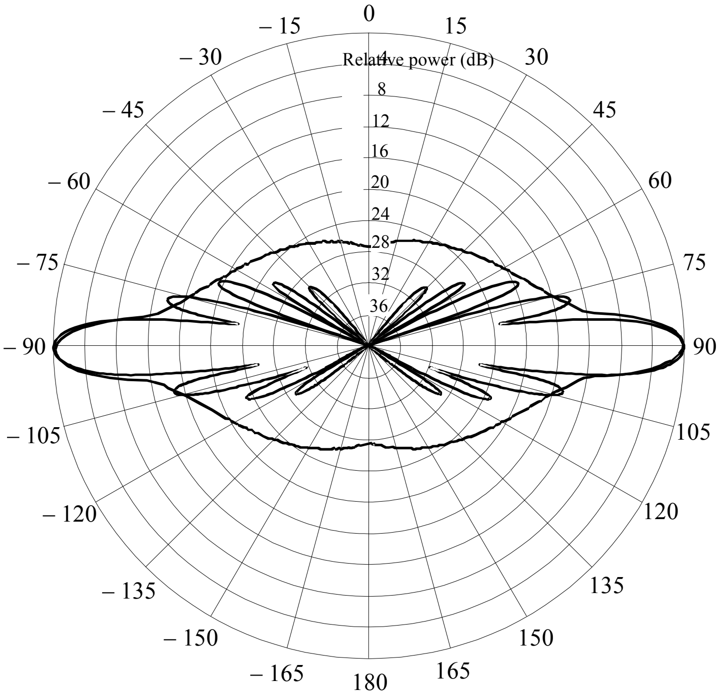
[84] *See* National Institute of Standards and Technology, Wireless Communications Technology Group, *General Purpose Calculator for Outdoor Propagation Loss*, *available at* <http://w3.antd.nist.gov/wctg/manet/prd_propcalc.html> (last visited, Jan. 30, 2003) (offering propagation software).

from an L-band ATC base-station antenna visible at high elevation angles to airborne receivers.[85] The isolation value proposed by Inmarsat is about 10 dB based upon the reference pattern contained in the Recommendation. The antenna radiation pattern from the ITU-R is incorporated below as Figure 1.8.A.

Figure 1.8.A: Antenna Radiation Pattern (Figure 5, of Recommendation ITU-R F.1336)
Note – high values of gain discrimination at elevation angles above about 15 degrees (i.e., between –75° and +75° as shown on the figure).



This Figure compares a measured 900 MHz antenna pattern to its corresponding reference pattern. The measured pattern shows a significantly greater isolation than predicted by the reference pattern for elevation angles 30 degrees or greater from boresight. For elevation angles above 45 degrees from boresight, it appears that isolations above 36 dB are achievable, even with an antenna not specifically designed for ATC operations. This showing supports MSV's assertion that it is possible to obtain 40 dB of isolation above the base station antenna.

Inmarsat also contends that the tilt angle of the ATC base station antennas will be important. MSV indicated that the antenna tilt will be –5 degrees. This factor is taken into account in determining the potential for interference to aircraft terminals operating over the Inmarsat system.

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[85] *See* International Telecommunications Union, Recommendation ITU-R F.1336, *Reference Radiation Patterns of Omnidirectional, Sectoral and Other Antennas In Point-To-Multipoint Systems For Use In Sharing Studies In The Frequency Range From 1 GHz To About 70 GHz.*

1.9 Voice Activation Factor

A typical value for voice activation is in the range of 2 to 4 dB depending upon the system and the background noise at the location of the MT. MSV uses a value of 1 dB for the MT since it will likely be used in a noisy environment. It uses 4 dB for the base stations which assumes that the traffic it transmits will originate in a much less noisy environment than the handheld user MTs. These values are incorporated into our analyses.

Voice activation can also be used to account for the number of active BS carriers in a single cell sector, at a given instant in time due to voice usage. In the MSV system architecture there are three carriers in each sector and each carrier will either be on or off in each TDMA time slot because of voice effects. There is a long-term voice activation over several frames that further reduces the long-term average power. However, the power in a time slot is of primary concern since the GSM time-slot duration is 0.577 milliseconds and each time slot can impact several symbols of a digital message of another system. If it is assumed that two of the three carriers will be transmitting in the same time slot, the voice activation factor will be 1.8 dB. In our analysis, a voice activation factor of 1 dB is used for an aggregation of MTs, 4 dB is used for an aggregation of BS and 1.8 dB is used for a single BS sector.

1.10 Voice Encoder (Vocoder) Factor

MSV contends that use of voice encoders, or vocoders,[86] will reduce the amount of power from the MTs that would potentially interfere with the Inmarsat satellites. MSV maintains that a 7.4 dB reduction in interfering power could be associated with its use of a 2.4 kbps vocoder and that it is possible for some of its MTs to use 2.4 kbps while the remainder of its MTs use various vocoder rates between 2.4 and 13 kbps.

MSV asserts that a terminal that is terrestrially engaged in voice communications will be allocated the highest rate vocoder, and, will thus, be operating in full-rate GSM mode. MSV further asserts that, when its output power as reported to the system by the terminal exceeds an upper bound (say -10 dBW), that terminal will, via fast in-band signaling, be commanded to switch over to quarter-rate GSM mode (equivalent to satellite-mode). In this mode, that terminal now needs to transmit only one GSM burst once in every four GSM frames.[87] If an algorithm that links the data rate associated with a specific user terminal to that user terminal's transmit power level is incorporated in the ATC system, the effective power of the user would be reduced by 7.4 dB. That is, the vocoder data rate can be used in conjunction with the active power control to reduce interference at the expense of total system capacity. This can be done by having user terminals requesting high transmit powers automatically switched to lower data rates, and, therefore, make fewer transmissions. This lower effective data rate lowers the effective or average power of the user while actually increasing the amount of power available for structural attenuation on a per-burst basis.

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[86] Voice encoders are used to digitize the human voice for delivery over a digital communications system. The quality of the reproduced voice depends upon the algorithms used to encode and decode voice and the data rate of the resulting digital voice representation. The standard GSM vocoder data rate is about 13 kbps. MSV maintains that using an algorithm with a data rate of 2.4 kbps would reduce the power of all users by 7.4 dB (10*log(13/2.4)).

[87] MSV Jan. 29, 2003 *Ex Parte* Letter at 3.

Assuming that various vocoder rates range between 13 kbps and 2.4 kbps, Table 1.10.A shows the number of TDMA frames that would be skipped between MT transmission, the associated transmit duty cycle and transmit power of the MT. If a vocoder is implemented, the power increase and duty cycle would balance so that the time-averaged transmit power would remain constant. It is our expectation that the TDMA time-slots vacated by an MT in order to reduce its transmit duty cycle would not be utilized by another MT.

Table 1.10.A Vocoder Associated Transmit Power and Duty Cycles

Vocoder Rate (kbps)	No. Skipped TDMA Frames	MT Transmit Duty Cycle	Transmit Power (dBW)[88]
13	0	100 %	X
6.5	1	50 %	X+3.0
3.25	3	25 %	X+6.0
2.6	4	20 %	X+7.0
2.4	Average of 4.4	18.2 %	X+7.4

Unlike the MT to BS power control factor, the average power reduction obtained by using a vocoder will be dependent upon the distribution of users. For example, if a user is within a building at the maximum structural attenuation, the MT will be transmitting at the peak power of 0 dBW, however, the duty cycle of the MT will be at 18.2%. The time averaged power radiated out of the structure by the MT will be 7.4 dB below the maximum amount of structural attenuation budget in the cellular design (i.e, on a time-averaged basis the reduction in duty cycle will lower the effected radiated power by 10*log(18.2/100) = 7.4 dB). A user in an automobile near the edge of the cell will be operating somewhat below the maximum amount of structural attenuation budget in the cellular design at a duty cycle of perhaps 25%. An outdoor user would be operating with the GSM 13 kbps vocoder operating at 100% duty cycle. Table 1.10.B calculates the average power reduction factor resulting from the use variable rate vocoder based upon these assumptions and the user distribution described by Dr. Vogel given in subsection 1.2. While MSV states that the vocoder reduces the effective interference power by 7.4 dB, Table 1.10.B indicates that a vocoder factor of only 3.5 dB should be used in our interference analyses.

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[88] In this instance ‘X’ is intended to stand for a specific level of MT transmit power. This specific level could depend on a number of factors such as the allowable structural attenuation, permitted peak power, etc.

Table 1.10.B Calculation of Vocoder Power Reduction Factor

User Location	Percent Population (%)	Duty Cycle (%)	Weighted Duty Cycle
Outdoor	30	100	0.30
In Car	30	25	0.08
In Building	40	18	0.07
		Sum =	0.45
	Average Vocoder Power Reduction (dB) =		-3.5

In our analysis we use a vocoder factor of 3.5 dB under the assumption that the lower vocoder rates would be used exclusively to reduce the interference to other MSS satellites and systems and not to increase the number of MSV ATC users. Our analyses also recognize that the number of permitted MSV ATC base stations will depend upon the implementation of this vocoder data-rate/power control relationship.

1.11 Inmarsat Antenna Discrimination

Inmarsat maintains that it has no more than 20 dB of antenna discrimination to the MSV coverage area in which ATC would be deployed.[89] Inmarsat later showed the details of one of the Inmarsat-4 antenna coverage patterns, which MSV then used to divide the Inmarsat coverage in to 9 distinct areas, each associated with a gain level derived from the Inmarsat information.[90] Using the data contained in the MSV analysis, Table 1.11A derives the weighted antenna discrimination of the Inmarsat-4 antenna beam towards MSV's service area. The weighting is determined by multiplying the 'Relative Size' of the angular area by the attenuation, as a real number, that exists towards that area. The sum of the weighted values is the average discrimination toward the total angular area.

Table 1.11 A Calculation of Area Weighted Antenna Discrimination

Area No.	Size Sq. Deg.	Relative Size	Discrimination dB	Weighted Discrimination
1	0.19	0.005	-22.5	0.000027
2	0.2	0.005	-27.5	0.000009
3	0.88	0.023	-30.0	0.000023
4	0.71	0.018	-27.5	0.000032
5	2.63	0.068	-22.5	0.000380
6	3.83	0.098	-19.0	0.001238
7	4.67	0.120	-22.5	0.000674
8	2.05	0.053	-27.5	0.000094
9	23.78	0.611	-30.0	0.000611
Sum	38.94	1.000		0.003088
Average Antenna Discrimination (dB) =				-25.1

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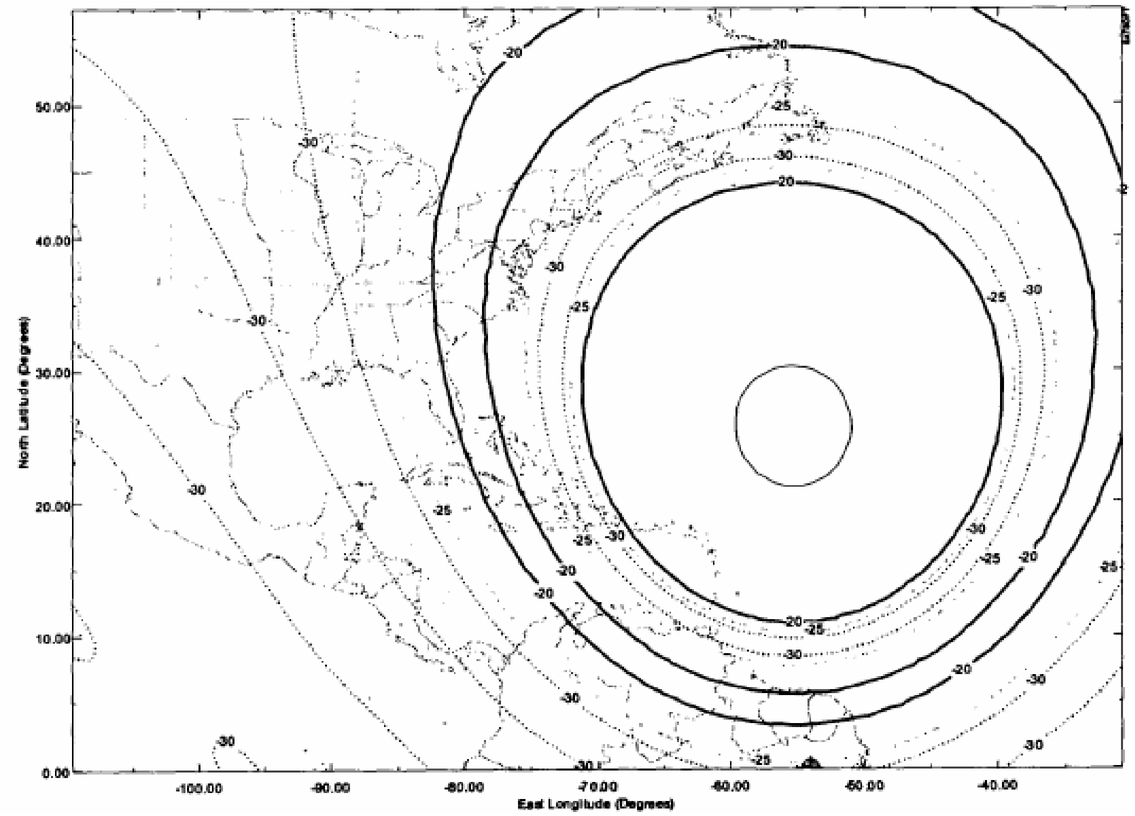
[89] Inmarsat Comments, Technical Annex, at 4.

[90] *See* MSV Nov. 4, 2002 *Ex Parte* Letter at 5.

MSV has stated that an Inmarsat antenna discrimination greater than 25 dBi would be required to share with MSV's MSS. MSV calculated that a fully loaded MSV MSS system would increase the delta T/T of the Inmarsat receiver by about 30% for this beam.[91] Inmarsat asserts that the beam under discussion is one that it expects to be able to share spectrum with MSV MSS operations in the absence of ATC. This would imply that an Inmarsat antenna discrimination greater than 25 dBi would be required to share with MSV's MSS. Only the antenna beams that can operate co-frequency with the MSV MSS interference are candidates for operating co-frequency with ATC. Therefore, the minimum Inmarsat discrimination towards MSV ATC coverage considered in co-frequency ATC analyses is 25 dB.

Figure 1.11 A Inmarsat Gain Roll-Off For Selected Inmarsat-4 Antenna Beam



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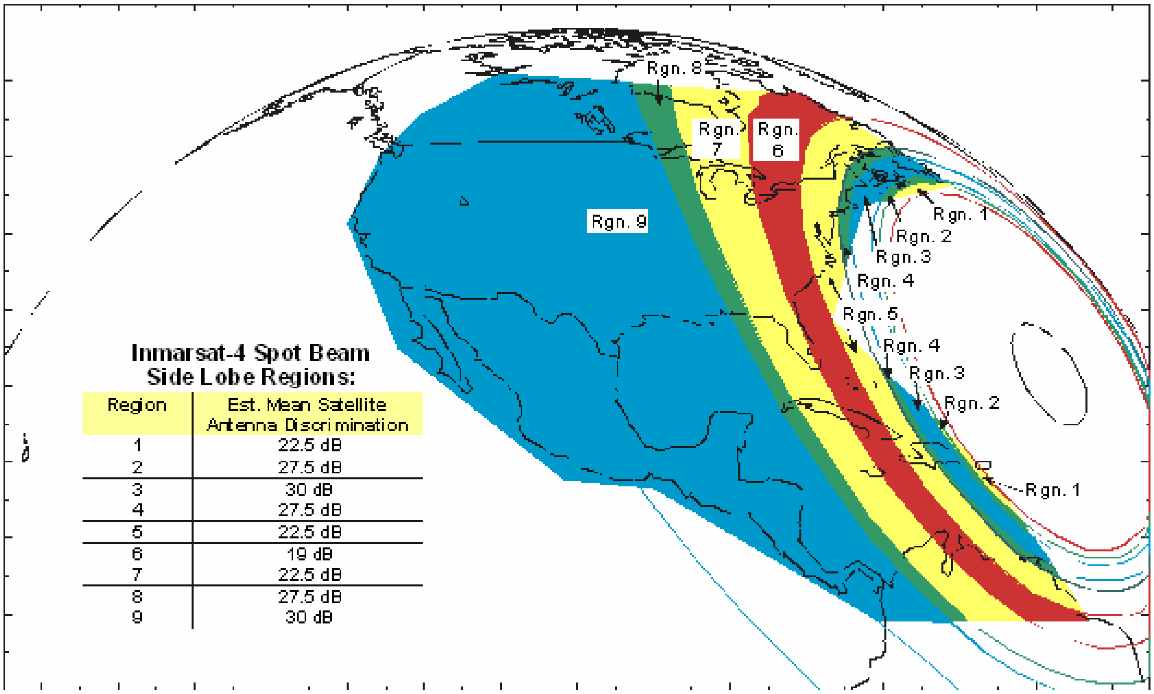
[91] *See* MSV Nov. 4, 2002 *Ex Parte* Letter at 5.

Figure 1.11.B Gain Discrimination Regions for Selected Inmarsat-4 Antenna Beam



Inmarsat-4 Spot Beam Side Lobe Regions:

Region	Est. Mean Satellite Antenna Discrimination
1	22.5 dB
2	27.5 dB
3	30 dB
4	27.5 dB
5	22.5 dB
6	19 dB
7	22.5 dB
8	27.5 dB
9	30 dB

1.12 Saturation levels in Inmarsat Receivers

Inmarsat contends that a saturation value of -90 dBm should be used for its receivers.[92] MSV contends that it has made measurements on an Inmarsat Mini-M receiver that showed that saturation did not occur until the input power reached about -45 dBm, some 45 dB higher than -90 dBm.[93] Additionally, some parties have quoted the Radio Technical Committee on Aeronautics (RTCA), which has a standard for -50 dBm for airborne terminals.[94]

GMDSS and AMS(R)S services are provided by Inmarsat and therefore its receivers should have similar performance characteristics. ARINC Characteristics 741 provides specifications on desensitization thresholds for AMS(R)S receivers. ARINC 741 specifies the gain of the front end (comprising the low noise amplifier (LNA) and diplexer) as being between 53 dB and 60 dB inclusive. In the same document, the 1 dB compression point occurs at a minimum front-end output level of 10 dBm. The saturation resulting in desensitization is attributed to the LNA. The worst-case front-end input level leading to desensitization is –50 dBm.

Given these potential values for saturation, we feel that the use of -50 dBm for airborne terminals and -60 dBm for mass-produced terrestrial receivers is reasonable.

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[92] *See* Inmarsat Comments, Technical App., Table 3.3-2, dated October 22, 2001. The actual term that appears in the Table is -120 dBW, which is equivalent to -90 dBm.

[93] *See* MSV Reply, Technical App. at 14.

[94] *See* Boeing April 8, 2002 *Ex Parte* Letter at 10.

1.13 MSV MSS Frequency Reuse Factor

MSV states that its next-generation satellite will have approximately 200 beams and will use a 7 cell frequency plan. This, it argues, yields a (200/7 = 28.6) 28 fold frequency reuse factor, allowing it to reuse each frequency 28 times within the satellite coverage area. Inmarsat provides a statistical analysis that, using a number of assumptions, shows that the MSV frequency reuse factor is closer to 8 or 10.[95] The Inmarsat analysis makes the following assumptions:

- The MSV antenna beams are each assigned a number from F-1 to F-7 which is a typical 7 cell reuse plan.
- All the beams are equal in size.
- Traffic volume is distributed exponentially and randomly from beam to beam.
- The bandwidth assigned to any beam is determined by the maximum traffic of any of the beams of the same F number. (In other words, all F-1 beams will be assigned the necessary bandwidth to handle the highest level of traffic in the F-1 beam).

Inmarsat then sums the total traffic assigned to all of the beams (calling it the “gross spectrum” or 100.2 MHz) and divides it by the sum of the maximum bandwidths assigned to the individual F1 to F7 cells (calling this the “net spectrum” or 12.0 MHz). Inmarsat then concludes that the frequency reuse is actually (100.2/12.0 =) eight. The study does not, however, take into account the fact that both the beam sizes and frequency assignments would be optimized to maximize revenue. This means that, for example, the F-1 beam directed near Arizona wouldn’t necessarily have the same assigned bandwidth as the F-1 beam covering Philadelphia. Nor, would it necessarily be the same size beam. The major factor in optimizing the beam size and frequency assignments is the potential for interference from the closest beams with overlapping frequency assignments. Therefore, the ability to optimize beam size and frequency use within a multi-beam antenna is not unlimited. The result of this optimization will be an increase in the ratio of traffic to assigned bandwidth throughout the MSS system, increasing the effective frequency reuse of the satellite above Inmarsat’s example. While a reuse of 8 or 10 is considered too small, a reuse factor of 28 would occur only with a completely balanced, homogenous, traffic pattern across the United States. The MSS traffic can not be expected to be totally balanced. We expect that a frequency reuse factor on the order of 20 would be a more appropriate value to use in our analysis.

In addressing MSV’s reuse of MSS frequencies for ATC operations, Inmarsat also argued that, based upon its assessment of MSV’s beam roll-off utilization and satellite pointing capabilities, MSV would require additional spectrum beyond that used for its MSS operations.[96] Inmarsat based its argument on certain assumptions on the placement of MSV’s ATC base stations with respect to the -10 dB beam contour and on MSV’s antenna-pointing accuracy.[97] Satellite pointing errors on the order of those used by MSV are technically feasible. We do not find Inmarsat’s arguments persuasive.

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[95] *See generally* Inmarsat May 10, 2002 *Ex Parte* Letter, Attach. at i-v.

[96] *See* Inmarsat May 21, 2002 *Ex Parte* Letter, Attach. at 1-12.

[97] Specifically, MSV claims that satellite pointing errors of 0.04 degrees in roll and 0.05 degrees in pitch are possible. Inmarsat adds 0.15 degrees simultaneously in all directions to its description of the MSV’s beam patterns. *See* Inmarsat May 21, 2002 *Ex Parte* Letter at 5.

1.14 Number of MSV ATC Terminals to be used in Interference Analysis

The maximum number of ATC transmitters that can be simultaneously active is an important parameter in determining the potential interference to other systems. MSV proposes to limit the number of transmitting ATC users on its own network by measuring the increased noise-floor of its satellite receiver and to adhere to a maximum increase in the satellite noise floor of 0.25 dB. Inmarsat contends that not only is it very difficult to reliably measure this small increase in noise at the satellite, but MSV MES operating with other MSV satellite antenna beams will obscure the ATC MT measurement. We agree that, without special techniques that no party has explained or demonstrated, it will be very hard to measure reliably the stated increase in the MSV satellite receiver noise floor.

An alternative to measuring the increase in satellite noise floor would be to limit the number of ATC users that correspond to the 0.25 dB increase in the MSV noise floor. The ATC users transmit in the satellite receiver frequency band, so the increase in noise floor is directly attributable to the number of simultaneously transmitting ATC users. The difficulty is that the classic method of regulating the number of users would be to issue a blanket license for a specific number of ATC user terminals and, unfortunately, the ratio of the number of simultaneously transmitting users to total number of users is unknown for this new application. However, each transmitting user terminal must be associated with a base station carrier transmission. Therefore, it is possible to relate the number of base station carriers operating on a specific frequency to the maximum number of simultaneously transmitting users and, indirectly, limit the associated increase in satellite receiver noise floor.

Table 1.14.A provides a calculation of the maximum number of the simultaneous user transmitters required to increase the MSV satellite noise floor by 0.25 dB, and the corresponding maximum number base station carriers. Since this approach assumes that 100% ATC system occupancy results in a 0.25 dB satellite noise floor increase, it does not allow for any amount of excess capacity that would be designed into a system under realistic peak load conditions. As a result, it will lead to a lower bound estimate on the number of base stations required to maintain an increase in MSV satellite noise floor of 0.25 dB. That is, under realistic loading conditions, MSV could deploy more base stations and reasonably expect to maintain the 0.25 dB ATC system limit. However, the values calculated in Table 1.14.A will protect the other MSS systems from unacceptable interference.

Table 1.14.A Calculation of Number of MSV ATC Base Stations

Term	Units	Value
Calculation of Maximum Allowable Interference		
MSV Satellite Gain	(dBi)	41
Satellite Receive Noise Temperature	(K)	450
Satellite Noise Density (No)	(dBW/Hz)	-202.1
Allowable Degradation in Beam using Frequency F1	(dB)	0.25
Maximum Degraded Noise Floor (No+Io)	(dBW/Hz)	-201.8
Maximum Allowable Interference Density (Io)	(dBW/Hz)	-214.3
Calculation Interference Received from One MT		
MT Peak EIRP	(dBW)	0.0
MT Bandwidth	(kHz)	200
MT EIRP Density	(dBW/Hz)	-53.0
Average Free Space Loss	(dB)	188.3
Average Outdoor Blockage to MSV Satellite	(dB)	0.5
MSV Average Satellite Antenna Discrimination	(dB)	10
Power Control Factor	(dB)	20.0
Vocoder Factor	(dB)	3.5
Polarization Isolation	(dB)	1.4
Voice Activity Factor for MT	(dB)	1.0
Received Interference Power Density per User	(dBW/Hz)	-236.7
Calculation of Allowed Simultaneous Users per Beam		
Total Allowed Interference Density (from above)	(dBW/Hz)	-214.3
Individual Average MT Interference Density (from above)	(dBW/Hz)	-236.7
Simultaneous Users on Frequency F1	(dB)	22.4
Simultaneous Users on Frequency F1	(#)	173
Number of Base Station Carriers on F1	(#)	173
Approximate Number of Beams over CONUS using F1	(#)	10
Number Base Station Carriers in CONUS on F1	(#)	1725

MSV has stated that it would implement a GSM-like 8 slot TDMA ATC system. Assuming this type of system is implemented, each base station carrier will have one MT, and only one MT, transmitting to it at any time. Table 1.14.A provides a calculation of the number of base stations that may operate on a specific frequency while providing a 0.25 dB increase in the noise level of an MSV satellite receiver on that frequency. Assuming one MT per base station carrier, the resulting number of base station carriers that would be permitted to operate would be about 1725 per 200 kHz of bandwidth assigned to MSV.

In some of its analyses, MSV assumed a total of 90,000 MTs transmitting simultaneously in addition to the assumed 2000 MTs transmitting on a single frequency. This means that it has assumed a total of (90,000/2000 =) 45 separate 200 kHz ATC channels in use. This further assumes a total of (45 * 200 kHz =) 9 MHz of spectrum devoted to ATC downlink and another 9 MHz of ATC uplink. The amount of spectrum actually available to MSV for ATC is the same as the MSV spectrum negotiated between the other L-band MSS operators for MSS operations up to its licensed limit. Since this spectrum is expected to vary annually in accordance with the L-band MOU, we cannot say determine how many ATC channels will exist at any one time. Additionally, as discussed above, we find that the maximum number of MTs on a single channel should be about 1725 as opposed to MSV's number of 2000. This implies that the total number of ATC MTs could vary from the number 90,000 assumed by MSV. For the purposes of assessing the potential for interference to other systems, some number of simultaneously transmitting MTs will have to be assumed. We use MSV's value of 90,000 while noting that the total number of simultaneously transmitting MTs could, in fact, be less.

As shown in Table 1.14.A, limiting the number of simultaneously transmitting MTs to about 1725 will limit the noise increase at the MSV satellite receiver to 0.25 dB. This number of base station carriers, or equivalently, the number of MTs on a channel, is predicated on three important assumptions:

1) that the licensee will implement a vocoder that can be used to reduce the time-averaged EIRP of the MT when operated at high peak EIRPs (see section 1.10);
2) that the licensee will not substitute other MT transmissions in the TDMA time slots left empty by the reduction in MT duty cycle that results from use of the vocoder; and,
3) that the ATC cells will be designed so that, at a minimum, 18 dB of structural attenuation margin is reserved within the link budget (see section 1.2).

If these conditions are not met then the number of allowable BS carriers should be reduced.

2.0 Intra-Service Interference Analyses

Inmarsat and MSV currently share the L-band spectrum with three other GSO MSS systems visible from the United States. MSV, the United States satellite operator; Inmarsat, a United Kingdom company; and TMI, a Canadian company, are authorized to serve end users in the United States. Mexico and Russia are also parties to the Mexico City Memorandum of Understanding. Sharing between these systems is accomplished by their use of geographic and frequency separation. In the geographic regions served by both Inmarsat and MSV, the satellites use different frequencies (i.e., frequency separation). Where the two systems serve different geographic areas of the United States, the two systems may use the same frequencies (i.e., through geographic separation). An additional MSS system, operated by the Japanese, has requested to join the multilateral coordination to gain access to these same frequency bands.

2.1 Potential Interference from ATC Operations to Inmarsat Satellite Receivers

Inmarsat indicates in its comments that it expects high levels of interference to its satellite receivers from MSV's ATC MTs and base stations. Inmarsat contends that its currently operating Inmarsat-3 and its future generation system, the Inmarsat-4 network, will be affected by MSV's ATC operations. MSV maintains that any increase in noise to Inmarsat's systems should be compared with the interference that is produced by MSV's currently operating MSS system. NTIA analyzed the potential for interference to an Inmarsat satellite receiver due to its use of Inmarsat to support GMDSS and AMS(R)S operations.[98] NTIA used a number of different assumptions we have. For example, NTIA assumed a polarization loss factor of 0 dB, a transmit power control factor of 3 dB and a shielding loss of 10 dB. Our assumptions are discussed in Subsection 1. As a result of the use of different assumption, we disagree with the NTIA calculation.

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[98] *See* NTIA Nov. 12, 2002 *Ex Parte* Letter, Encl. 4 at 1-7.

The first of the following analyses evaluates the ratio of interference from MSV's current MSS traffic and compares it to the potential ATC interference to Inmarsat's current and future satellite networks. The second analysis, contained in section 2.1.2, uses a less complex approach to determine the expected increase in the noise floor of the Inmarsat-3 and Inmarsat-4 satellites.

2.1.1 Calculation of Interference to Inmarsat Satellites

Adjacent Band Analysis. Table 2.1.1.A calculates the amount of noise received by Inmarsat's satellite receivers assuming both the MSV and Inmarsat satellite systems are providing service to the same geographic region in different sub-bands of the L-band (i.e. they are sharing the L-band using frequency separation). The amount of noise produced by the current MSV MSS system is compared to future MSV MSS and ATC operations. The results of this analysis are summarized in Table 2.1.1.B.

Table 2.1.1.A - Comparison of Current Operations and Future MSS and ATC Terminal Usage on Inmarsat-3 and Inmarsat-4 for Adjacent Band Situation

Parameter	Units	Inmarsat 3 Current Terminal	Inmarsat 3 MSS Terminal	Inmarsat 3 ATC Terminal	Inmarsat 4 Current Terminal	Inmarsat 4 MSS Terminal	Inmarsat 4 ATC Terminal
Inmarsat G/T	(dB/K)	-1.45	-1.45	-1.45	12.87	12.87	12.87
Noise Temp	(K)	700	700	700	650	650	650
Noise Density (No)	(dBW/Hz)	-200.2	-200.2	-200.2	-200.5	-200.5	-200.5
MT EIRP	(dBW)	16	5	0	16	5	0
Bandwidth	(kHz)	6	50	200	6	50	200
MT EIRP Density	(dBW/Hz)	-21.8	-42.0	-53.0	-21.8	-42.0	-53.0
Inmarsat Gain	(dBi)	27	27	27	41	41	41
Max OOB	(dBW/Hz)	-79.5	-103	-103	-79.5	-103	-103
Propagation Loss	(dB)	188.7	188.7	188.7	188.7	188.7	188.7
Outdoor Blockage	(dB)	0.0	0.0	3.1	0.0	0.0	3.1
Power Control Factor	(dB)	0.0	2.0	20.0	0.0	2.0	20.0
Vocoder Factor	(dB)	0.0	0.0	3.5	0.0	0.0	3.5
Voice activity	(dB)	0.0	3.0	1	0.0	3.0	1
Polarization Isolation	(dB)	0.0	0.0	1.4	0.0	0.0	1.4
Received Power	(dBW/Hz)	-241.2	-269.7	-293.7	-227.2	-255.7	-279.7
Received I	(K)	0.055	0.000	$3x10^{-7}$	1.38	0.002	0.00001
Delta-T/T per MT	(%)	0.008	0.00001	$4x10^{-8}$	0.21	0.0003	$1x10^{-6}$
Max No. MT Carriers[99]	(#)	1800	1800	90000	1800	1800	90000
No. Beams Over CONUS	(#)	4	4	4	100	100	100
Sum delta-T/T	(%)	14.1	0.02	0.0004	382	0.54	0.11
Total delta-T/T per Inmarsat Beam	(%)	3.5	0.005	0.001	3.82	0.005	0.001

The impact of future MSV operations, both ATC and MSS, on current and future Inmarsat satellites will be significantly less than the current sharing situation in the L-band. Table 2.1.1.B compares the percentage of increased noise that would be received by the currently operating Inmarsat satellites and its future generation system, Inmarsat-4, from the MSV system as it currently configured to operate and its proposed ATC operations when sharing through frequency separation is implemented.[100]

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[99] *See* MSV Jan. 11, 2002 *Ex Parte* at 22 (providing estimate of fully loaded MSS system).

[100] *See* MSV Jan. 10, 2002 *Ex Parte* Letter at 22.

Table 2.1.1.B – Comparison of Inmarsat Received Interference to Current Interference with Frequency Separation

Adjacent Band	Inmarsat-3	Inmarsat-4
Ratio of Future ATC Noise to Current MSS Noise	0.03%	0.03%
Ratio of Future MSS Noise to Current MSS Noise	0.14%	0.14%
Ratio Future Total [MSS+ATC] Noise to Current MSS Noise	0.17%	0.17%

In sum, the results contained in the table indicate that, for Inmarsat-3, the expected noise increase due to the MSV ATC will be only 0.03% of the noise increase it is currently experiencing from MSV's MSS system. The combined noise increase from MSV's ATC and future MSS operations would be less than one quarter of one percent (0.17%) of the current MSV operations. The same ratio of future ATC noise to current MSS system noise and future ATC plus MSS noise to current MSS system noise apply to the Inmarsat-4 satellite. One of the conclusions that can be drawn from this table is that the interference to the future generation of Inmarsat satellites is lower if the next generation of MSV satellite is implemented.

It should also be noted that the noise increase, in the out-of-band case treated in Table 2.1.1.A, for both the Inmarsat-4 satellite and the Inmarsat-3 receiver is the same value (i.e., 0.001%).

Adjacent Beam Analysis. Table 2.1.1.C calculates the amount of noise received by Inmarsat's satellite receivers assuming both the MSV and Inmarsat satellite systems are providing service to different, but adjacent, geographic regions on the same frequency (i.e., they are sharing the L-band using geographic separation). The amount of noise produced by the current MSV MSS system is compared to future MSV MSS and ATC operations. The results of this analysis are summarized in Table 2.1.1.D.

Table 2.1.1.C - Comparison of Current Operations and Future MSS and ATC Terminal Usage on Inmarsat-3 and Inmarsat-4 for Adjacent Beam Situation

Parameter	Units		Inmarsat 3			Inmarsat 4	
		Current Terminal	MSS Terminal	ATC Terminal	Current Terminal	MSS Terminal	ATC Terminal
Inmarsat G/T	(dB/K)	-1.45	-1.45	-1.45	12.87	12.87	12.87
Noise Temp	(K)	700	700	700	650	650	650
Noise Density (No)	(dBW/Hz)	-200.2	-200.2	-200.2	-200.5	-200.5	-200.5
MT EIRP	(dBW)	16	5	0	16	5	0
Bandwidth		6	50	200	6	50	200
MT EIRP Density	(dBW/Hz)	-21.8	-42.0	-53.0	-21.8	-42.0	-53.0
Required OOB Reduction	(dBW/Hz)	0.0	0.0	0.0	0.0	0.0	0.0
Max OOB	(dBW/Hz)	-21.8	-42.0	-53.0	-21.8	-42.0	-53.0
Relative Power Density	(dB)	0.0	-20.2	-31.2			
Inmarsat Gain	(dBi)	27	27	27	41	41	41
Propagation Loss	(dB)	188.7	188.7	188.7	188.7	188.7	188.7
Antenna Discrimination	(dB)	22	22	22	25	25	25
Outdoor Blockage	(dB)	0.0	0.0	3.1	0.0	0.0	3.1
Power Control	(dB)	0.0	2.0	20.0	0.0	2.0	20.0
Vocoder Factor	(dB)	0.0	0.0	3.5	0.0	0.0	3.5
Voice activity	(dB)	0.0	3.0	1.0	0.0	3.0	1.0
Polarization Isolation	(dB)	0.0	0.0	1.4	0.0	0.0	1.4
Received Power	(dBW/Hz)	-205.5	-230.7	-265.7	-194.7	-219.7	-254.7
Received I	(K)	205	0.6	0.0002	2581	7.8	0.002
Delta T/T One carrier	(%)	29.3	0.1	0.00003	397	1.2	0.0004
Max # Co-freq Carriers	(#)	2	20	1725	2	20	1725
Total Delta T/T	(%)	58.6	1.8	0.05	794.1	23.9	0.7

The impact of future MSV operations, both ATC and MSS, on current and future Inmarsat satellites will be significantly less than the current sharing situation in the L-band. Table 2.1.1.D compares the percentage of increased noise that would be received by the currently operating Inmarsat satellites and its future generation system, Inmarsat-4, from the MSV system as it currently operates and its proposed ATC operations when sharing through geographic separation is implemented.

Table 2.1.1.D – Comparison of Inmarsat Received Interference to Current Interference with Geographic Separation

For Adjacent Beam Situation	Inmarsat-3	Inmarsat-4
Ratio of Future ATC to Current MSS Noise	0.08%	0.08%
Ratio of Future MSS to Current MSS Noise	3.02%	3.02%
Ratio Future Total [MSS+ATC] to MSS Current	3.10%	3.10%

The results contained in the table indicate that, for Inmarsat-3, the expected noise increase due to the MSV ATC will be only 0.08% of the noise increase it is currently experiencing from MSV's MSS. The combined noise increase from MSV's ATC and future MSS operations would only be about three percent of the current MSV operations, with the majority coming from the MSS operations. In a similar fashion, Table 2.1.1.D indicates that the noise increase in the Inmarsat-4 satellite receivers due to ATC is only 0.08% of the noise increase that would occur due to the current generation of MSV MSS operations. The conclusion to be drawn from Tables 2.1.1.B and 2.1.1.D is that the future use of the L-band by MSV should be significantly friendlier to other L-band satellites than if the MSV MSS system were to continue in its present configuration.

It should also be noted that the noise increase, in the co-frequency case treated in Table 2.1.1.C, for the Inmarsat-4 satellite is 0.7% and for the Inmarsat-3 receiver 0.05%. Because the noise increase calculated in Table 2.1.1.A for the out-of-band band case is so small, adding the results of Table 2.1.1.A and Table 2.1.1.B to obtain the total noise increase for Inmarsat-4 results in a noise increase of only 0.7%. In a similar fashion, the total Inmarsat-3 noise increase should be on the order of 0.05%. The result is that neither Inmarsat-3 nor Inmarsat-4 should be hindered by ATC operations.

The major factor in MSV's argument is the difference in power density of the current and future terminals. The current L-band MSS terminal transmits 16 dBW (40 Watts) in a 6 kHz bandwidth giving it an in-band power density of –22 dBW/Hz. The next generation MSS terminal, operating in satellite mode, is projected to have a power density 20 dB less than (i.e., 1/100th of) the current MSS terminal and the ATC terminals are projected to have power density 30 dB below (i.e., 1/1000th of) the current MSS terminal. As a result, comparing a user population of 1800 current MSS terminals with a population of 90,000 ATC terminals, the ATC system will perform very favorably even without consideration of a number of valid ATC isolation factors such as outdoor blockage, polarization, power control, etc.

This analysis addresses the implementation of ATC within the United States. In performing this analysis, we have assumed that MSV would implement ATC around 100 of its 200 beams in the next generation satellite system. This has resulted in two estimates for the number of MTs: (1) 1725 transmitting on a co-frequency basis and (2) 90,000 MTs transmitting on an adjacent-channel basis. If MSV were to implement ATC outside of the United States, the number of terminals could, at most, be twice the number allowed inside of the United States.[101] Based upon Tables 2.1.1.A and 2.1.1.C, the total noise increase in the Inmarsat-4 receiver would be on the order of 1.4%. The noise increase for the Inmarsat-3 satellite receiver would be on the order of 0.1%. Neither of these noise increases should hinder the Inmarsat operations.

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[101] This is a conservative assumption because, according to MSV, approximately 20 MSV satellite beams cover the ocean or the Gulf of Mexico and are not associated with land areas. *See* MSV *Ex Parte* Jan. 11, 2002 at 14. Therefore ATC could not be implemented in these beams.

2.1.2 Alternative Approach to Estimating Increase in delta-T/T in the Inmarsat Satellites

Another approach to assess the level of interference that would be caused by MSV's ATC system to Inmarsat's satellites is to evaluate the change in the noise temperature of the Inmarsat system based on MSV limiting its self-interference noise increase to 0.25 dB. For this approach, we assume that a number of parameters are the same for both satellite systems. These parameters include: propagation loss, polarization isolation, main beam gain, outdoor blockage, power control, voice activation, and vocoder factor.

Table 2.1.2.A calculates the interference that would be caused to the Inmarsat system, based on MSV's intra-system interference target of 0.25 dB, and based on the following other assumptions: the average MSV antenna discrimination to its own MTs will be 10 dB;[102] for the out-of-beam case (i.e., co-frequency use in adjacent geographical regions) the Inmarsat-3 satellite has 22 dB of antenna discrimination toward the MSV ATC users and the Inmarsat-4 satellite has 25 dB of antenna discrimination; and for the out-of-band case (i.e., coverage of the same geographical regions by using frequency separation) the MSV ATC terminals have 50 dB of out-of-band attenuation.[103] The results of the calculations in Table 2.1.2.A are summarized in Table 2.1.2.B.

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[102] MSV Jan. 10, 2002 *Ex Parte* Letter at 21.

[103] Inmarsat maintains that the Inmarsat-4 satellite, with a maximum spot beam gain of 41 dBi, will only have 20 dB of discrimination toward MSV's ATC transmitter. *See* Inmarsat Comments, Technical Annex, § 3.1. However, the Inmarsat-3 satellite that has a spot beam maximum gain of 27 dBi will have 22 dB of discrimination. Based upon the calculation in Section 1.11, we use a 25 dB discrimination value for the Inmarsat-4 adjacent beam discrimination. As shown in Table 2.1.2.A, the resulting "Total Delta T/T" changes from 0.25% with an antenna discrimination of 25 dB to 2.1% with an antenna discrimination of 20 dB. This is still significantly below the 6% used to trigger inter-satellite coordination. Additionally, the difference in blockage between the MSV satellite and Inmarsat satellite has not been taken into account in this conservative analysis. Adding this factor will reduce the impact of ATC transmissions on Inmarsat's satellites.

Table 2.1.2.A: Calculation of the Increase in Noise Floor of Inmarsat Satellites

Parameter	Units	MSV MT	Inmarsat I3 Case 1 In-band	Inmarsat I4 Case 1 In-band	Inmarsat I3 Case 2 In-beam	Inmarsat I4 Case 2 In-beam
Satellite Rec. Noise Temp.	(K)	450	700	650	700	650
Satellite Noise Density (No)	(dBW/Hz)	-202.1				
Allowed Degradation	(dB)	0.25				
Allowed No+Io	(dBW/Hz)	-201.8				
Allowed Interference Den. (Io)	(dBW/Hz)	-214.3				
Effective MSV User Power	(dBW/Hz)		-57.0	-57.0	-57.0	-57.0
Satellite Gain	(dBi)	41.0	27.0	41.0	27.0	41.0
Relative Loss	(dB)	188.3	188.7	188.7	188.7	188.7
Relative Sat Antenna Discrimination	(dB)	10.0	22.0	25.0	0.0	0.0
Relative Spectrum Roll-Off	(dB)	0.0	0.0	0.0	50.0	50.0
Effective MSV User Power	(dBW/Hz)	-57.0				
Inmarsat Interference Per MSV Beam	(dBW/Hz)		-240.7	-229.7	-268.7	-254.7
No. Inmarsat Beams per MSV Beam	(#)				25	3
No. of Co-Frequency Beams			29[104]	29		
Inmarsat Interference	(dBW/Hz)		-226.2	-215.2	-254.8	-250.0
Inmarsat Interference	(K)		1.75	21.97	0.002	0.007
Total Delta-T/T	(%)	5.9	0.25	3.4	0.0003	0.001

The analysis in Table 2.1.2.A first calculates the total ATC MT power density on the surface of the Earth that would be required to increase the MSV noise floor by 0.25 dB, the amount that MSV indicated as its intra-system interference target. That MT power density is then used to calculate the resulting increased noise floor of the Inmarsat satellites. In calculating the increase in noise floor of the Inmarsat satellites, the factors that are taken into account are the differences in the antenna gain between the MSV and Inmarsat systems and the out-of-band roll-off of the ATC MTs. Inmarsat contends that there would be little or no difference in the amount of outdoor signal blockage between the ATC user and Inmarsat's satellites and the ATC user and MSV's satellite. Though we disagree with this contention (see section 1.2), this analysis assumes the blockage between the ATC user and the MSV satellite is identical to the blockage between the ATC user and the Inmarsat satellite in order to be conservative. It should be noted, however, that the Inmarsat satellites will be seen by the ATC user at an average elevation angle *lower* than the

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[104] The value of 29 co-frequency MSV beams assumes that the MSV satellite has 200 independent beams and uses a 7-fold frequency reuse plan. We address this value in more detail in Section 1.13 and use a value of 29 here because it is conservative.

ATC user relative to the MSV satellite (i.e., several dB of additional signal blockage should be expected toward the Inmarsat satellite).

Table 2.1.2.B – Comparison of Inmarsat Received Interference in Adjacent Band and Adjacent Beam

	Inmarsat-3 Delta-T/T	**Inmarsat-4 Delta-T/T**
Adjacent Band	0.0003%	0.001%
Adjacent Beam	0.25%	3.38%

In sum, Table 2.1.2.B shows that the worst case increase in Inmarsat's noise floor is well below six percent for the adjacent beam case and only one one-thousandth of one percent for the adjacent band case even with conservative baseline assumptions about blockage. The conclusion to be drawn from this calculation is that the increase in the noise floor of the Inmarsat satellite from ATC operations should not be a problem. ATC operations should not hamper Inmarsat's current or future operations as long as the MSV satellite noise floor increase due to ATC is less than 0.25 dB. All of the analyses by MSV and Inmarsat involve either out-of-band or adjacent beam sharing. In general, the Inmarsat satellites appear to have more discrimination, either via antenna beam discrimination or out-of-band emission attenuation, to the ATC transmitters than the MSV satellite has. As a result, the noise-floor of Inmarsat's satellite receivers should be less affected by MSV's ATC MTs than MSV's own satellite receivers.

2.2 Potential Interference from MSV ATC Base Stations to Inmarsat Mobile Earth Station (MES) Receivers

Inmarsat is concerned about the potential for interference into its MES receivers from MSV's ATC base stations. This potential for interference may exist in four ways: (1) overload[105] of the Inmarsat land-based MES receivers when they are near an ATC base station; (2) out-of-band interference to the Inmarsat land-based MES receivers from ATC base stations; (3) aggregate interference to an airborne Inmarsat MES receiver from a relatively large number of MSV base stations visible from an aircraft; and (4) overload of an airborne Inmarsat MES receiver from an ATC base station. Each of these potential interference situations is evaluated below.

2.2.1 Analysis of Potential Interference to Inmarsat MES in an Urban Environment

The following paragraphs address sharing between MSV ATC base stations and Inmarsat MSS terminals in urban environments. An urban environment will contain areas dominated by tall buildings and other structures, where the RF signal undergoes larger attenuations for a given distance than would be experienced in rural areas. On the other hand, there are areas that will be free of tall buildings such as airports, harbors and waterways in which free space propagation can be expected. The following paragraphs address both types of areas.

2.2.1.1 Overload of an Inmarsat MSS MES by an MSV Base Station

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[105] Receiver "overload" or "saturation" occurs when the input total power is sufficient to drive the receiver from its normal, operational linear state, into a non-linear state. The resulting non-linear state provides distortion of the desired input signals and, for severe overload, the inability of the receiver to operate.

Inmarsat claims that an MSV base station, when seen at a distance of 100 meters, will produce a signal 60 dB higher than that which would saturate or overload one of its MES receivers. This claim is based upon a number factors:

(1) Inmarsat assumes that MSV will use 25 carriers per cell[106] while MSV states that the maximum carriers per cell in its design is only three;[107]

(2) Inmarsat argues that its MES will "overload" or saturate when exposed to –120 dBW of interfering power.[108] This number converts to –90 dBm. MSV provided measurements of an Inmarsat Mini-M terminal which indicated that saturation did not occur until the input power reached about –45 dBm (about 45 dB higher than Inmarsat's stated value).[109] A value of –60 dBm is used in this analysis. The -60 dBm value is still considerably more conservative than the -45 dBm threshold measured by MSV;

(3) Inmarsat assumes that the gain of the MSV base station antenna would be 0 dBi when an MES terminal is 100 m from a base-station antenna. In practice, the antenna would typically be on a tower or building and the angle from the base-station antenna main-beam to the MES receiver would be on the order of 25 degrees. MSV uses a gain discrimination value of –12.5 for this situation. An ITU-R Recommendation incorporated in Inmarsat's comments indicates that this value could be as low as –24 dB.[110] The –12.5 dB value supported by MSV is therefore much more conservative; and

(4) Inmarsat assumes free-space loss between the base station and the MES receiver (i.e., at 100 m there would be a 76 dB loss). This free-space loss calculation is close to the calculated free-space-loss if the antenna were on a 30-meter tower and the user stands 100 m away from the tower. MSV uses the WI propagation model that, it states, predicts 94 dB of loss for the same case.[111] Other urban propagation models give a range of expected loss from 80 to 97 dB.[112] A value of 86 dB is used in the following analysis, when assuming operations in an urban environment.[113] For non-urban environments free-space propagation is assumed.

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[106] Inmarsat Comments, Technical Annex at 9.

[107] MSV Reply, Technical App. at 17.

[108] Inmarsat Comments, Technical Annex at 8.

[109] *See* MSV Reply, Technical App. at 14.

[110] *See supra* § 1.8, Fig. 1.8.A.

[111] The "WI model" refers to the Walfisch-Ikegami propagation model. The WI model addresses radio propagation in urban and suburban areas.

[112] *See* National Institute of Standards and Technology, Wireless Communications Technology Group, *General Purpose Calculator for Outdoor Propagation Loss*, *available at* <http://w3.antd.nist.gov/wctg/manet/prd_propcalc.html> (last visited, Jan. 30, 2003) (offering propagation software).

[113] *See supra* § 1.6.

By factoring for three vs. 25 carriers per MSV cell, using –60 dBm as the Inmarsat MES overload threshold, and taking into account the antenna pattern to which Inmarsat referred in its comments, any signal propagation loss greater than 86 dB from the base station to the Inmarsat MES should be sufficient to protect the Inmarsat receiver from overload interference. All of the propagation models, except the WI line-of-sight model, predict a loss greater than 86 dB. The actual loss is a strong function of the surrounding environment and the propagation model used. Since all of the urban and city propagation models predict a loss significantly higher than the free-space model proposed by Inmarsat, we conclude that Inmarsat's MES should not experience overload in the presence of ATC base stations in urban areas.

The following table, Table 2.2.1.1.A, shows the three link budgets used by Inmarsat, MSV and us in our respective analyses. Our link budget shows a positive margin against a conservative saturation value of –60 dBm. This should be sufficient to prevent saturation in a reasonably constructed MSS terminal.

Table 2.2.1.1.A Link Budgets Examining Possibility of Saturation of Inmarsat Mobile Earth Stations (MES) in Urban Areas

Parameter	Units	Inmarsat	MSV	Staff
Base Station EIRP	(dBW/200 kHz)	19.1	19.1	19.1
Total BW per Sector (3 carriers)	(MHz)	5	0.6	0.6
Max. No. Carriers per Sector	(#)	25	3	3
Distance	(m)	100	100	100
BS to MES Propagation Loss	(dB)	76.0	95.5	86
Power Control	(dB)	6.0	6.0	5.2
Voice Activation	(dB)	4.0	4.0	4.0
Polarization Isolation	(dB)	3.0	8.0	8.0
Inmarsat Gain to BS	(dB)	0.0	0.0	0.0
BS Gain to Inmarsat	(dB)	0.0	-12.5	-12.5
Received Interference	(dBW)	-55.9	-102.1	-91.8
Saturation level	(dBW)	-120	-75	-90
Saturation Level	(dBm)	-90	-45	-60
Margin	(dB)	-64.1	27.1[114]	1.8

Realizing that urban and city propagation models predict a loss significantly higher than the free space model, overload interference from ATC base stations to Inmarsat MES in an urban environment is not expected to be problematic. It is possible, however, that in limited urban situations, the loss between an Inmarsat terminal and a base station may be less than the 86 dB mentioned above. This is expected to occur rarely, but could cause occasional, limited periods of saturation in Inmarsat terminals operating in these areas. This must be considered in light of the already limited usage of L-band terminals in urban settings due to line-of-sight interruption between the Inmarsat terminals and the satellite due to building, trees and other obstructions. If, hypothetically, an Inmarsat terminal in an urban environment would be saturated while being within 100 meters of an ATC base station and the radius of the ATC cell was 1 km, then the percentage of restricted area operation for the Inmarsat terminal would be given by the ratio of

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[114] We note that we could not reproduce MSV's calculated the received signal power level of–101.9 dBW or the resulting margin of 26.9 dB.

the area of restricted operations to that of the ATC cell or ($100^2/1000^2 = 0.01$ or) 1%. For a 6 km cell radius cell the ratio is 0.03%. Therefore, the increase in the area in which an Inmarsat terminal might have difficulty in communicating with the satellite could be slightly increased. This should be compared with the increase in urban area served by an MSS system using ATC, which would be the majority of the urban area.

It should be stressed that in an urban environment, it will be possible in most instances to operate an Inmarsat MES well within 100 meters of an ATC base station. In many locations, the Inmarsat terminal will be shadowed from the base station due to buildings and other man-made objects, and the loss between the Inmarsat terminals and the base station will be higher than indicated above. In an urban environment, particularly at ranges beyond 100 meters, the path loss between the ATC base station and the Inmarsat terminal should be greater than predicted by the free space model and the Inmarsat terminal should not suffer overload. Furthermore, we believe that the saturation level we have selected for the Inmarsat terminal is quite conservative in estimating the potential for interference.

2.2.1.2 Protection of Inmarsat Terminals in Urban Areas – Out-of-Band Interference

Inmarsat expressed its concern about the possibility of out-of-band interference from an MSV ATC base station to Inmarsat's MES receivers. The details of both Inmarsat's and MSV's analyses are contained in Table 2.2.1.2.A, below. Table 2.2.1.2.A also contains, in the last column, the values that would result from the assumptions we made in Section 1 of this Appendix. The basic differences in the analyses are as follows:

(1) MSV states that Ericsson, MSV's ATC-equipment manufacturer, has committed to a specific out-of-band suppression level of -57.9 dBW/MHz (-118 dBW/Hz)[115] for the base stations, whereas Inmarsat uses a value of –27 dBW/200 kHz (-80 dBW/Hz)[116] creating a difference of almost 40 dB in the assumed radiated power;

(2) Inmarsat assumes that there is no antenna gain discrimination from the ATC base station to the Inmarsat terminal. As discussed above and in section 1.8, this term should be between MSV's proposed value of –12.5 dB and –24 dB, the lowest possible value according to Figure 1.8.A;

(3) The propagation loss between the transmitter and receiver in an urban environment is also a factor and is similar to the overload analysis, above; and

(4) MSV assumes an 8 dB polarization isolation factor[117] and Inmarsat proposes a 3 dB polarization factor.[118] MSV substantiated the 8 dB factor through both theory and measurement.

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[115] *See* MSV Jan. 11, 2002 *Ex Parte* Letter at 26; MSV Comments, Ex. E at 1-8.

[116] Inmarsat Comments, Technical Annex, Table 3.4-1.

[117] *See, e.g.,* MSV Jan. 11, 2002 *Ex Parte* Letter at 27; MSV May 1, 2002 *Ex Parte* Letter at 4.

[118] Inmarsat Comments, Technical Annex, at 20.

Table 2.2.1.2.A: Potential Out-of-Band Interference from MSV ATC Base Stations to Inmarsat MES

Parameter	Unit	Inmarsat Value	MSV Value	Staff Value
BS In-band EIRP per 200 kHz	(dBW)	19.1		
OOB Attenuation (re Inmarsat)	(dB)	46.1		
Assumed EIRP Toward MES	(dBW)	-27.0		
OOB Power to Ant. Re MSV/Ericsson	(dBW/MHz)		-57.9	
BW Conversion (dBMHz/200 kHz)	(dB)		7.0	
Power to Ant. In Inmarsat band	(dBW/200 kHz)		-64.9	-64.9
BS Main beam Gain	(dBi)		16.0	16.0
BS ant discrimination to MES	(dB)	0.0	-12.5	-12.5
EIRP Towards MES	(dBW/200 kHz)	-27.0	-61.4	-61.4
Distance to Antenna	(m)	100.0	100	100
Free space loss	(dB)	-76.0		
WI non-line of sight	(dB)		-95.5	
Average of FSL/WI				-86
Power Control	(dB)	6.0	6.0	5.2
Voice Activity	(dB)	4.0	4.0	1.8
Polarization Isolation	(dB)	3.0	8.0	8.0
Gain Inmarsat MES to BS	(dB)	0.0	0.0	0.0
Sum of Attenuation factors	(dB)	89.0	113.5	101.0
Received Int.	(dBW/200 kHz)	-116.0	-174.9	-162.4
Received Power Spectral Density	(dBW/Hz)	-169.0	-227.9	-215.4
MES Receive Noise Temp	(K)	150.0	290.0	290.0
MES Noise Power	(dBW/Hz)	-206.8	-204.0	-204.0
Increase in Noise	(%)	611,672	0.4	7.2
I/N	(dB)	37.9	-23.9	-11.4

Taking all of the above factors into account leads to the conclusion that an Inmarsat MES would experience a noise increase of about 7% as opposed to the 600,000% predicted by Inmarsat.[119] The interference-to-noise ratio (I/N) that corresponds to delta T/T of 7% is -11 dB. This means that the interference power will be, at most, less than 1/10th of the noise power of the receiver. Furthermore, the Inmarsat MES receiver performance should not be adversely affected by the MSV base station because the small transient degradation experienced by the mobile terminals would occur for only a short amount time due to the mobile use of the terminal.

2.2.1.3 Protection of Inmarsat Terminals in Open Areas

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[119] Inmarsat claims that the resulting increase in noise will be 600,000%. *See* Inmarsat Comments, Technical Annex at 20.

Table 2.2.1.3.A assumes both the Inmarsat receiver and MSV Base Station are operating in an urban environment. Areas such as airports and harbors and waterways offer large building-free areas where the signal propagation from the base station to the receiver is best characterized by free space propagation. The following paragraphs examine possible interference to Inmarsat and other terminals operating around airports and on waterways. The terminal used for this analysis is similar to the Inmarsat Mini-M terminals, which have a maximum of 6 dB of gain. Because of the broad antenna beam width associated with the Mini-M terminal, we have assumed that two ATC base stations are in the terminal's main beam.

Inmarsat Terminals in Airports. Table 2.2.1.3.A calculates the required distance between the MSV base station and an Inmarsat receiver to avoid saturation. An Inmarsat terminal utilizing a relative low gain antenna, such as the Mini-M terminal, is assumed. The resulting distance, 470 m, is approximately 1550 ft. The power flux density, equivalent to a -60 dBm received signal, for a single base station according to the assumptions in Table 2.2.1.3.A, is -73.0 dBW/m^2 in 200 kHz.

Table 2.2.1.3.A Required Separation between Inmarsat Receiver and MSV Base Station (Free Space Propagation)

Parameter	Units	Value
Base Station EIRP	(dBW/200 kHz)	19.1
Total BW per sector (3 carriers)	(MHz)	0.6
Max carriers per sector	(#)	3
Number of Base Stations Visible	(#)	2
Distance	(m)	470
BS to MES Loss	(dB)	89.4
Polarization Isolation	(dB)	8.0
Voice Activation	(dB)	1.4
Power Control	(dB)	5.2
BS Gain to Inmarsat	(dB)	-12.5
Inmarsat Gain to BS	(dB)	0
Received Level	(dBW)	-90.0
Assumed Saturation level	(dBW)	-90.0
Margin	(dB)	0.0

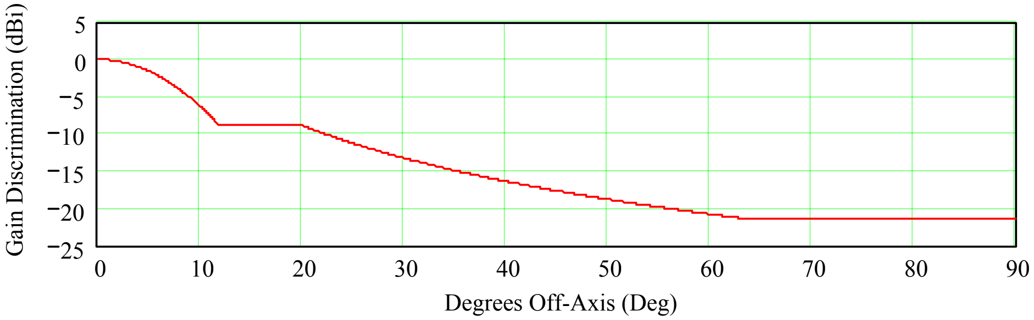
2.2.2 Protection of GMDSS/Inmarsat Receivers from ATC Base Stations

Inmarsat terminals may also be located in harbors and on waterways. The frequency band 1530-1544 MHz is allocated to the GMDSS. This international application is connected to and required by international treaty resulting from the Safety of Life at Sea (SOLAS) Convention. Inmarsat receivers often operate within the GMDSS service. In harbors and on navigable waterways, Inmarsat terminals with larger antennas such as the Inmarsat-B terminals, will likely be used. Table 2.2.2.A shows the elevation angle of the highest operational Inmarsat satellite as seen from a number of United States cities. As can be seen in the Table, there is always an Inmarsat satellite visible above 30 degrees elevation. Figure 2.2.2.A presents the discrimination pattern for a 21 dBi gain Inmarsat terminal. This Figure was developed using Recommendation ITU-R M.694 which contains a reference radiation pattern for MSS shipboard antenna operating around 1.5 to 1.6 GHz. The figure shows that the gain discrimination at 30 degrees is 13.2 dB.

Table 2.2.2.A Inmarsat Elevation Angles from Specific Cities

City	Inmarsat AORW 54 W	Inmarsat POR 142 W	Highest Elevation (Deg)
Washington, DC	40.7	11.2	40.7
Boston, MA	38.1	5.3	38.1
Miami, FL	48.4	16.9	48.4
Dallas, TX	30.6	29.0	30.6
Denver, CO	20.8	30.4	30.4
Bismarck, ND	32.3	18.0	32.3
Seattle, WA	7.4	37.2	37.2
San Francisco, CA	8.5	41.9	41.9
San Diego, CA	14.0	43.7	43.7

Figure 2.2.2.A Inmarsat-B Antenna Discrimination Pattern



In order to analyze the impact of ATC base stations on a GMDSS receiver, two cases will be considered: 1) receiver saturation (or desensitization) and 2) out-of-band interference. The scenario used in each analysis involves an ATC base station transmitter with an antenna height of 30 meters and a GMDSS receive antenna that has a height of 7 m. The analysis will consider a 1500 meter separation distance between the ATC base station and the GMDSS receiver. The Inmarsat B antenna shown in Figure 2.2.2.A will be used to determine the GMDSS receive antenna gain. The base station antenna is assumed to be tilted down at a 5 degree angle, is viewed at about 5 degrees off-axis and a minimum of about 5 dB gain back-off from the antenna mainbeam exists.

NTIA analyzed the effect of ATC base stations on GMDSS terrestrial receivers in a manner significantly different than the approach used in the following paragraphs.[120] NTIA calculated the maximum EIRP that a base station could transmit without causing interference to a shipboard GMDSS receiver under the condition that the GMDSS receiver was located at a worst case distance from the base station. This worst case distance was determined by calculating the highest PFD, at the assumed height of the GMDSS receive antenna, using a base station antenna pattern at two different antenna heights. We disagree with NTIA that limiting the BS EIRP is the most useful approach. When necessary, we prefer to determine a separation distance between the BS and the possible location of a ship carrying a GMDSS receiver that will still protect GMDSS operations.

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[120] *See* NTIA Nov. 12, 2002 *Ex Parte* Letter, Encl. 3 at 1-12.

2.2.2.1 GMDSS/Inmarsat Receiver Saturation

As discussed earlier, a value of –60 dBm (-90 dBW) will be used in this analysis for the desensitization threshold. Table 2.2.2.1.A provides the link calculation for GMDSS receiver desensitization.

Table 2.2.2.1.A GMDSS Receiver Saturation Calculation

Parameter	Units	Value
ATC BS Antenna Height	(m)	30
GMDSS Antenna Height	(m)	7
Horizontal Distance Between ATC BS and GMDSS	(m)	1500
Slant Range	(m)	1500.2
Frequency	(MHz)	1540
ATC BS Peak EIRP per Carrier	(dBW/200 kHz)	19.1
Carriers per Sector (3)	(dB)	4.8
ATC BS Peak EIRP per Sector	(dBW)	23.9
ATC BS Antenna Gain Back-off	(dB)	-5.0
ATC BS Power Control	(dB)	-5.2
Polarization Loss	(dB)	-8.0
ATC BS Voice Activation	(dB)	-1.8
GMDSS Antenna Gain	(dBi)	21.0
GMDSS Antenna Discrimination	(dB)	-13.2
Propagation Loss	(dB)	-99.8
Received Power	(dBW)	-88.1
GMDSS Receiver Desensitization	(dBW)	-90
Margin	(dB)	-1.9

The link calculation in Table 2.2.2.1.A shows a margin of –1.9 dB. The calculated received power level at the GMDSS receiver input is –88.1 dBW compared to the saturation threshold of -90 dBW. Because of the expected range in signal levels for saturation (-80 to -90 dBW) and the possibility of additional propagation loss above free space, the GMDSS receiver should be protected for the EIRP of 19.1 dBW and a separation distance of 1.5 km.

2.2.2.2 Out-of-Band Interference to GMDSS/Inmarsat Receivers

The GMDSS receiver system noise level is used to assess the potential of interference from the out-of-band emissions of ATC base stations. The GMDSS receiver system noise level is calculated using the following equation:

$$N = -172.1 \text{ dBm/Hz}^{121} + 10 \text{ Log } (BW_{GMDSS}) - 30$$

For a GMDSS receiver bandwidth of 15 kHz, the system noise level is –160.3 dBW/15 kHz. Table 2.2.2.2.A provides the link calculation for GMDSS receiver out-of-band interference.

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[121] RTCA/DO-210C, *Minimum Operational Performance Standards for Aeronautical Mobile Satellite Services (AMSS)*, 26 (Jan. 16, 1996).

Table 2.2.2.2.A Out-of-Band Interference to GMDSS Receiver Calculation

Parameter	Units	Value
ATC BS Antenna Height	(m)	30
GMDSS Antenna Height	(m)	7
Horizontal Distance Between ATC BS and GMDSS	(m)	1500
Slant Range	(m)	1500.2
Frequency	(MHz)	1540
ATC BS Out-of-Band Power to Antenna	(dBW/200 kHz)	-64.9
Carriers per Sector (3)	(dB)	4.8
ATC BS Mainbeam Antenna Gain	(dBi)	16.0
ATC BS Antenna Gain Back-off	(dB)	-5.0
ATC BS Voice Activation	(dB)	-1.8
ATC BS Power Control	(dB)	-5.2
ATC BS Effective EIRP in GMDSS Band	(dBW/200 kHz)	-56.1
Propagation Loss	(dB)	-99.8
Polarization Loss (BS-LHCP, Inmarsat-RHCP)	(dB)	-8.0
GMDSS Mainbeam Antenna Gain	(dBi)	21
GMDSS Antenna Discrimination	(dB)	-13.2
Receiver Bandwidth Correction	(dB)	-11.2
Received Interference Power in GMDSS Receiver	(dBW)	-167.3
GMDSS Receiver Noise Level	(dBW)	-160.3
Margin	(dB)	7.0

As shown in Table 2.2.2.2.A, for an ATC BS out-of-band emission level of –64.9 dBW/200 kHz[122] and a 1.5 km (0.9 mile) separation distance, the interference level in the GMDSS receiver is 7 dB below the system noise. This would result in an increase of the system noise by 0.8 dB and should provide adequate protection for GMDSS receivers. However, in order to ensure that the –64.9 dBW/200 kHz out-of-band emission level in the GMDSS band is maintained, the MSS operator providing the ATC should be required to reduce its emissions below the –64.9 dBW/200 kHz used in the analysis. One reference states that the emission for a GSM TDMA signal is down 40 dB at the adjacent TDMA carrier frequency.[123] That is, the emission is down 40 dB at a separation of 200 kHz from the carrier. To obtain the out-of-band emission level of –64.9 dBW/200 kHz, significantly more than 40 dB of attenuation is required. How this requirement is satisfied is the responsibility of the MSS operator providing ATC.

Table 2.2.2.2.A shows a link calculation with the base station located 1.5 km from the waterway in which the Inmarsat-B terminal equipped ship is located. At 1.5 km, the BS antenna, which is tilted down at a 5 degree angle, is viewed at about 5 degrees off-axis and with a minimum of about 5 dB gain back-off from the antenna mainbeam. Because the beamwidth of the Inmarsat-B terminal is significantly less than that of the Mini-M terminal, we assume that only a single base station will be operating near the main beam.

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[122] This is taken to be that same level as -57.9 dBW/MHz discussed in MSV's Jan. 10, 2002 *Ex Parte* Letter. MSV stated that Ericsson, its ATC equipment manufacturer, has committed to the specific out-of-band suppression level of -57.9 dBW/MHz.

[123] Dr. Jerry D. Gibson, ed., The Mobile Communications Handbook, 410 (CRC Press, 1999).

If the base station is located 1.5 km from the waterway, and has clear visibility to the waterway, Table 2.2.2.2.A shows that the Inmarsat-B terminal receiver should have no difficulty in operating. Additionally, with the base station 1.5 km from the waterway, it will appear to be less than 1.2 degrees above the horizon and the propagation loss in most situations will be greater than free space loss. We conclude that a 1.5 km separation between the BS and constricted, navigable waterway should be sufficient to protect an Inmarsat receiver on a ship.

An alternative method to protect the Inmarsat-B type of terminal on a waterway would be to constrain the PFD produced by a base station to be less than that required to saturate an Inmarsat-B terminal. Table 2.2.2.2.B shows that a PFD equal to -64.6 dBW/m^2 in 200 kHz with the mainbeam of the antenna coupled into the Inmarsat-B terminal would produce a received power of -60 dBm (the assumed saturation level of the receiver). Therefore, a requirement either to constrain base stations to maintain a 1.5 km distance from navigable, constricted waterways or to illuminate the edge of the waterway with a PFD no greater than -64.6 dBW/m^2 in 200 kHz with the base station antennas tilted at -5 degrees from the horizontal should protect the Inmarsat terminals on ships from interference.

Table 2.2.2.2.B Derivation of Received Power at Suggested PFD Limit

Item	Units	Value
Allowable PFD	(dBW/m^2 in 200 kHz)	-64.6
Inmarsat-B Gain	(dBi)	21.0
Antenna Discrimination	(dB)	-13.2
Isotropic Area	(dBm^2)	-25.2
Polarization Isolation	(dB)	-8.0
Received Power LHCP	(dBW/200 kHz)	-90.0
Conversion to dBm	(dB)	30.0
Received Power LHCP	(dBm)	-60.0

The above analyses indicate that it is possible to protect Inmarsat receivers in open areas such as around airports and harbors by placing limits on the installation of MSV ATC base stations. Specifically, if the base station is no closer to an airport than 470 meters or has a PFD below -73.0 dBW/m^2 in 200 kHz at the edge of the airport runways and stand areas and the base station is installed at least 1.5 km from a harbor or navigable waterway or has a PFD below -64.6 dBW/m^2 in 200 kHz at the edge of the navigable waterway or harbor, then the potential interference to these types of Inmarsat terminals would be significantly reduced if not eliminated.

2.2.3 Potential Interference to Airborne AMS(R)S/Inmarsat Terminals

The frequency band 1545-1555 MHz is allocated to the aeronautical mobile satellite en-route service (AMS(R)S) in the space-to-Earth direction. AMS(R)S is reserved for communications relating to safety of flights (see Provisions No. 1.36, 1.59, 5.37A, and Article 44 of the international Radio Regulations). Inmarsat receivers are often used in the AMS(R)S service. In order to analyze the impact of ATC base stations on AMS(R)S receivers, two cases will be considered: 1) out-of-band interference and 2) receiver desensitization. As discussed earlier, the threshold of -50 dBm is used for the receiver-desensitization analysis. An interference threshold based on 6% of the total noise corresponding to an interference-to-noise ratio (I/N) of –12.2 dB is used for the out-of-band analysis.[124]

NTIA analyzed the effect of ATC BS on AMS(R)S terrestrial receivers in a manner significantly different than the approach used in the following paragraphs.[125] NTIA calculated the maximum number of BS base stations that would be required to cause interference to an airborne AMS(R)S terminal. NTIA assumed that the AMS(R)S terminal would be located 270 meters above the BS. We disagree with NTIA that this static model provides a reasonable description of the way an aircraft receiver would operate and choose, instead, to use a Monte Carlo approach as described below.

2.2.3.1 Potential Interference to Airborne AMS(R)S Receivers

Inmarsat performed an analysis to assess the possibility of an airborne Inmarsat terminal experiencing out-of-band interference from the aggregate of a large number of MSV ATC base stations that could be visible from a worst case altitude of 302 m (1000 ft). From 302m, a circular area approximately 100 miles from edge-to-edge would be visible to the aircraft.[126] Inmarsat's analysis conservatively assumes that there would be 1000 base stations in this area. Inmarsat also disagrees with MSV that the base station antennas will have significant overhead antenna discrimination to the aircraft. Inmarsat refers to Recommendation ITU-R F.1336[127] as evidence that, at best, an isolation of only about 10 dB is available from the L-band base-station antennas at high elevation angles. MSV claims that a maximum isolation of 40 dB is achievable. As discussed more fully in Section 1.8, we agree with MSV.

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[124] *See* Recommendation ITU-R M.1234, *Permissible Levels of Interference in a Digital Channel of a Geostationary Satellite Network in the Aeronautical Mobile-Satellite (R) Service (AMS(R)S) in the Bands 1545 to 1555 MHz and 1646.5 to 1656.5 MHz and its Associated Feeder Links Caused by Other Networks of this Service and the Fixed Satellite Service* (1997), *available at* < http://www.itu.int/rec/recommendation.asp?type=items&lang=e&parent=R-REC-M.1234-0-199702-I > (last visited, Feb. 1, 2003).

[125] NTIA Nov. 12, 2002 *Ex Parte* Letter, Encl. 3 at 1-12.

[126] Assuming an MSV base station antenna height of 30 meters.

[127] *See* Recommendation ITU-R F.1336, *Reference Radiation Patterns Of Omnidirectional, Sectoral And Other Antennas In Point-To-Multipoint Systems For Use In Sharing Studies In The Frequency Range From 1 GHz To About 70 GHz*, *available at* <http://people.itu.int/~meens/pt2/RR/> (last visited, Feb. 4, 2003).

Table 2.2.3.1.A: Potential Interference to Inmarsat Airborne Receiver from ATC Base Stations

Item	Units	MSV	Monte Carlo Approach
EIRP per Carrier	(dBW)	19.1	
Bandwidth	(kHz/ch)	200	
EIRP density/carrier	(dBW/Hz)	-33.9	
Spurious EIRP density	(dBW/Hz)	-101.9	-101.9
Assumed Spurious Limit	(dB)	*-68.0*	*-68.0*
Carriers per sector	(#)	3.0	3.0
Voice activation	(dB)	4.0	4.0
Power control	(dB)	6.0	5.2
Polarization	(dB)	8.0	0.0
Spurious Emission average	(dBW/Hz)	-115.1	-106.3
Gain Disc. Inmarsat MES to Base Station	(dB)	0.0	0.0
Calculated Isolation	(dB)	-101.6	-105.1
Received interference power	(dBW/Hz)	-216.7	-211.4
Receiver Noise Temperature	(dBK)	25.0	25.0
Receiver Noise Temperature	(K)	316.2	316.2
Receiver Noise Density	(dBW/Hz)	-203.6	-203.6
Interference Temperature	(T)	15.5	52.1
Delta-T/T	(%)	4.9	16.5
Interference to Noise Ratio (Io/No)	(dBW/Hz)	-13.1	-7.8

Table 2.2.3.1.A addresses the details of the potential for interference to aircraft earth stations operating with the Inmarsat system. The calculations in the table are based on MSV's less complex, but still conservative approach. The key assumption made by MSV was that it will have 68 dB of out-of-band suppression in the Inmarsat band (see *italicized* entry in the table). As mentioned above, we independently verified, via a MathCad model, the isolation factor in the right-most column using a random ATC base station distribution. Our calculated value matches very closely the value used by MSV (i.e. 101.6 dB for MSV versus 105.1 dB for the MathCad model). We include the model as an attachment to this appendix. Note that no antenna discrimination was used for the Inmarsat antenna even though an airborne satellite antenna would be expected to have some, and perhaps a significant amount of shielding from terrestrial transmissions. The approach taken here is conservative.

In this case, Table 2.2.3.1.A shows that the worst case I/N is about –8 dB, which is 4 dB above the AMS(R)S receiver interference criteria of an I/N of –12.2 dB. Based on the analysis, to protect AMS(R)S receivers from ATC base station operations, the assumed spurious emission level could be reduced by 4 dB to -72 dB. However, based on the antenna specifications for AMS(R)S antennas the gain in the direction of the base station will be negative, which would provide additional isolation than that calculated in the analysis. Additionally, while no polarization discrimination is used in the analysis, the probability of having no polarization discrimination is remote. The situation improves dramatically as the aircraft altitude is increased. Therefore, this situation should cause no problems to AMS(R)S operations.

2.2.3.2 Overload of Airborne AMS(R)S/Inmarsat Terminals

The possibility of an airborne AMS(R)S/Inmarsat terminal being overloaded by ATC base stations was also evaluated. The analysis of potential saturation of airborne Inmarsat terminals assumes, again, a conservative 1000 base stations being visible from a 302 m (1000 ft.) altitude.

Table 2.2.3.2.A Evaluation of Potential for AMS(R)S Airborne Terminal Overload

Parameter	Units	MSV Value	Our Analysis
BS EIRP per carrier	(dBW)	19.1	19.1
Carriers per sector	(#)	3.0	3.0
Voice activation	(dB)	4.0	4.0
BS Power Control	(dB)	6.0	5.2
EIRP per sector	(dBW)	13.9	14.7
Polarization Isolation	(dB)	8.0	0.0
Gain Discrimination MES to Base Station	(dB)	0.0	0.0
Loss Factor from OOB analysis	(dB)	-101.6	-105.1
Effective power per Sector @ A/C	(dBW)	-95.7	-90.4
Power at A/C Receiver	(dBm)	-65.7[128]	-60.4
Overload Level	(dBm)	-50.0	-50.0
Margin	(dB)	15.7	10.4

The analysis shown in Table 2.2.3.2.A indicates that there exists a margin of 10 dB against receiver overload or saturation. Additionally, as indicated for the out-of-band case, as the altitude of the aircraft is increased, for example to 5000 ft, the margin against overload increases dramatically by approximately 9 dB to a total margin of 19 dB. Given the conservative nature of the model (e.g. antenna models, 1000 base stations, very low aircraft altitude, omnidirectional aircraft antenna, and no terrain shielding), overload from ATC base stations should not be an issue.

3.0 Inter-Service Interference Analyses

Several services are allocated in and adjacent to the 1525-1559 MHz and 1626.5-1660.5 MHz L-band MSS spectrum. Within the 1626.5-1660.5 MHz and 1525-1559 MHz bands, the Aeronautical Mobile Satellite, en-route Service (AMS(R)S), aeronautical terrestrial service, and Global Maritime Distress and Safety System (GMDSS) are allocated spectrum. Above 1660 MHz, the Radio Astronomy Service is allocated spectrum in the L-band. Within the 1525-1559 MHz band, Search and Rescue Satellite (SARSAT) downlinks operate in the 1544-1545 MHz band. Systems operate adjacent to the L-band spectrum as well. Below the 1626.5 MHz band, Big LEO MSS systems operate in the MSS allocation from 1610-1626.5 MHz. Below the 1525 MHz band edge, Mobile Aeronautical Telemetry systems operate in the 1435-1525 MHz allocation. Above the 1559 MHz band edge, GPS operations in the 1559-1610 MHz Radionavigation Satellite Service (RNSS) allocation. Figure 3.0.A is provided to show the various service allocations located adjacent to and within the L-band MSS allocations where MSV proposes to operate its ATC system.

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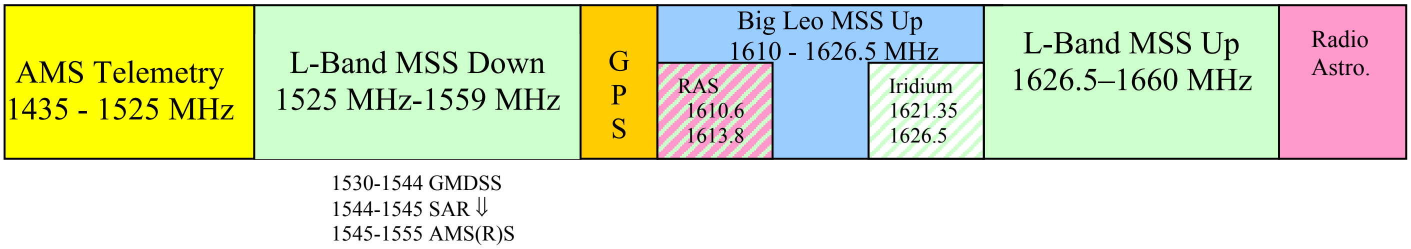
[128] MSV actually calculates this value as –60.7 dB. *See* MSV Jan. 10, 2002 *Ex Parte* Letter at 28 .

Figure 3.0.A: L-Band Service Allocations



3.1 AMS(R)S and GMDSS Operations Conditions

Communications systems operating in the frequency bands occupied by the AMS(R)S and GDMSS services must meet certain operating conditions. The following paragraphs address these conditions.

AMS(R)S Operating Conditions. Footnote US308 to the United States Table of Allocations provides priority to AMS(R)S systems in the upper L-band.[129] MSS operators authorized to provide MSS in the upper L-band are subject to meeting several conditions on their MES and Land Earth Stations (Gateways).[130] MSV's ATC operations could be required to protect AMS(R)S under the same conditions that apply to MSS systems operating in the upper L-band, in order to comply with footnote US308. MSV demonstrates in its comments how its ATC system would comply with the priority and preemption requirements with which MSS system must comply under US308. MSV asserts that its ATC network will possess inherent features for handling priority communications.[131] Specifically, MSV's ATC system will be capable of prohibiting entire populations of mobile terminals from accessing its system.[132] In addition to being capable of giving priority to AMS(R)S, the MSV system will also be capable of preempting active channels automatically and immediately (i.e., in less than one second, the MSV gateway would be able to allocate the preempted resource(s) to the AMS(R)S). Terminals would be preempted from providing MSS and ATC in the upper L-band through MSV's ability to simultaneously preempt corresponding satellite and terrestrial resources by the use of a centralized and common control facility for space and ground assets.[133] Based on MSV's explanation of its proposed ATC system, it appears to be able to meet the priority and preemption requirements that its current MSS system is obligated to meet and that its ATC system would therefore be capable of complying with US308.

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[129] *See* 47 C.F.R. § 2.106, n.US308.

[130] *See, e.g., Application of AMSC Subsidiary Corporation for a Blanket License to Construct and Operate up to 200,000 L-band Mobile Earth Stations*, Order and Authorization, File No. 2823-DSE-P/L-93, 1995 WL 109123, 12 & 18 (1995).

[131] MSV Comments, Technical App. at 7-11.

[132] MSV Comments, Technical App. at 7-11.

[133] MSV Comments, Technical App. at 7-11.

In the *Flexibility Notice*, the Commission noted that, according to Footnote US309, terrestrial stations are permitted to operate in the frequencies allocated to the AMS(R)S.[134] The Aviation Industry Parties and MSV do not take issue with US309 with respect to potential interference that could be caused to stations operating under the footnote allocation, but rather MSV contends that the footnote supports its claim that it is possible to have a footnote allocation for ATC similar to aeronautical terrestrial stations.[135] The regulatory issue of how to incorporate ATC in the Table of Allocations is not addressed in this Appendix.

GMDSS Operating Conditions. Footnote US315 to the United States Table of Allocations provides priority to the GMDSS in the lower L-band.[136] MSS operators authorized to provide MSS in the lower L-band are subject to meeting several conditions on their METs and Land Earth Stations (Gateways).[137] MSV's ATC operations could be required to protect GMDSS under the same conditions that apply to MSS systems operating in the lower L-band, in order to comply with footnote US315. MSV demonstrates in its comments how its ATC system would comply with the priority and preemption requirements that its MSS system must comply with according to US315. MSV asserts that its network will possess inherent features for handling priority communications.[138] Specifically, MSV's ATC system will be capable of prohibiting entire populations of mobile terminals from accessing its system.[139] In addition to being capable of giving priority to GMDSS, the MSV system will also be capable of preempting active channels automatically and immediately (i.e. in less than one second, the MSV gateway would be able to allocate the preempted resource(s) to the GMDSS). Terminals would be preempted from providing MSS and ATC in the lower L-band through MSV's ability to simultaneously preempt corresponding satellite and terrestrial resources by the use of a centralized and common control facility for space and ground assets.[140] Based on MSV's explanation of its proposed ATC system, it appears to be able to meet the priority and preemption requirements that its current MSS system is obligated to meet and that its ATC system would therefore be capable of complying with US315.

3.2 Systems Operating within the 1626.5-1660.5 MHz Portion of the L-Band Spectrum

The Radioastronomy Service (RAS) is allocated spectrum in the 1660-1660.5 MHz portion of the L-band to conduct scientific observations. RAS observatories are not located in urban or heavily populated areas; they are typically located in remote areas to avoid receiving noise caused by

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[134] *Flexibility Notice* 16 FCC Rcd at 15538, ¶ 12 n.27.

[135] Indeed, there are no terrestrial stations operating in conjunction with AMS[R]S systems currently in operation that could receive interference. *See* AIP Comments at 4-5 and 7.

[136] *See* Footnote US315 to the U.S. Table of Frequency Allocations, Section 2.106 of the Commission's Rules.

[137] *See L-Band MSS Rules Order*, 17 FCC Rcd at 2717-23, ¶¶ 30-45.

[138] MSV Comments, Technical App. at 7-11.

[139] MSV Comments, Technical App. at 7-11.

[140] MSV Comments, Technical App. at 7-11.

radio frequency transmitters.[141] The ITU has conducted studies and recommended appropriate protection requirements for RAS stations.[142] Consistent with the ITU studies, ATC operators could be required to take all practicable steps to avoid interference to United States RAS observations in the 1660-1660.5 MHz band, consistent with Recommendation ITU-R RA.769-1 of the international Radio Regulations.

3.3 Systems Operating within the 1525-1559 MHz Band Portion of the L-Band Spectrum

Search and Rescue Satellite (SARSAT) downlink operations exist in the 1544-1545 MHz band in accordance with Footnote 5.356 of the International Radio Regulations.[143] SARSAT uplink transmissions are located around 406 MHz from Emergency Position Indicator Radio Beacon (EPIRB) transmitters that are downlinked in the 1544-1545 MHz band to various earth station receivers located in the United States. The locations of these Earth stations are listed below in Table 3.3.A.

Table 3.3.A: Locations of SARSAT Receive Earth Stations

Location	**Latitude**	**Longitude**	**Nearby Local**
Alaska	64.9933 N	-147.5237 E	Fairbanks
California	34.6624 N	-120.5514 W	Vandenberg AFB
Florida*[144]	TBD	TBD	TBD
Guam	13.5783 N	144.9391 W	Guam
Hawaii	21.526 N	-157.9964 W	Oahu
Maryland	38.9955 N	-76.8513 W	NASA GSFC
Maryland	38.8510 N	-76.9310 W	Suitland
Puerto Rico**	18.4317 N500	-66.1922 W	Puerto Rico
Texas**	29.5605 N1	-95.0925 W	NASA Huston

(Note: In Table 3.3, a single "*" denotes a future SARSAT site and a double "**" denotes a site that is to be decommissioned.)

MSV is not authorized to provide MSS in the 1544-1545 MHz band so the potential for interference is strictly an out-of-band case. It is also noted from Table 3.3.A that some of the SARSAT earth stations are located in or near urban areas where ATC base stations would be located. In Table 3.3.B, we analyze the potential for interference between transmitting ATC base

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[141] 47 C.F.R. § 25.213(a)(1)(i), (ii) (listing RAS sites located in the United States).

[142] *See* Recommendation ITU-R RA.769-1, *Protection Criteria Used for Radioastronomical Measurements*, *available at* <http://people.itu.int/~meens/Pt2/Rec/RA769-1.pdf> (last visited, Feb. 1, 2003).

[143] *See* International Radio Regulations S5.356. S5.356 states that the use of the band 1544-1545 MHz by the mobile-satellite service (space-to-Earth) is limited to distress and safety communications). *See* Article S31). *See also* 47 C.F.R. § 2.106.

[144] There are several possible sites in Miami under consideration for a new local user terminal (LUT) location; however, the final decision has not been made. The LUT sites in Texas and Puerto Rico will be eliminated once the Miami LUT site is operational. There is also a possibility on a new LUT site at the Goddard Space Flight Center in Greenbelt, MD.

stations operating in bands adjacent to the receiving SARSAT earth stations. We base our analysis on the MSV ATC base stations being capable of meeting an out-of-band emission level of -57.9 dBW/MHz as in our other interference analyses.

Table 3.3.B: Analysis of SARSAT Avoidance Distance

Item	Units	Value	Comment
Nominal Center Frequency	(MHz)	1554.5	
Polarization			Note 1
Elevation Angle	(Degrees)	0	Note 2
Antenna Diameter	(m)	1.8	
SARSAT Gain (typical)	(dBi)	26.7	
SARSAT (G/T)	(dB/K)	4.0	
SARSAT Noise Temperature	(dBK)	22.7	
Receiver Noise Power	(dBW/Hz)	-205.9	
Allowable I/N	(dB)	-11.32	
Maximum Allowable Io	(dBW/Hz)	-217.2	
Receive Gain	(dBi)	26.7	
Isotropic Area	(dBm^2)	-25.3	
Receive Antenna Effective Area	(dBm^2)	1.5	
Allowable Power Flux at Antenna	(dBW/m^2 Hz)	-218.6	
MSV OOB Emission	(dBW/MHz)	-57.9	
MSV BS peak Antenna gain	dBi	16.0	
BS Gain Reduction Toward Horizon	dB	5.0	
Three BS Carriers	dB	4.8	
Power Control	dB	-2.3	
Voice Activation	dB	-1.8	
Polarization Discrimination	dB	0	
Peak Out-of-band Emission	dBW/MHz	-49.1	
MSV OOB Emission Density	(dBW/Hz)	-109.1	
Required Loss	(dBm^2)	134.8	
Maximum Interference Distance	(km)	85.6	
Maximum Interference Distance	(mi)	51.4	

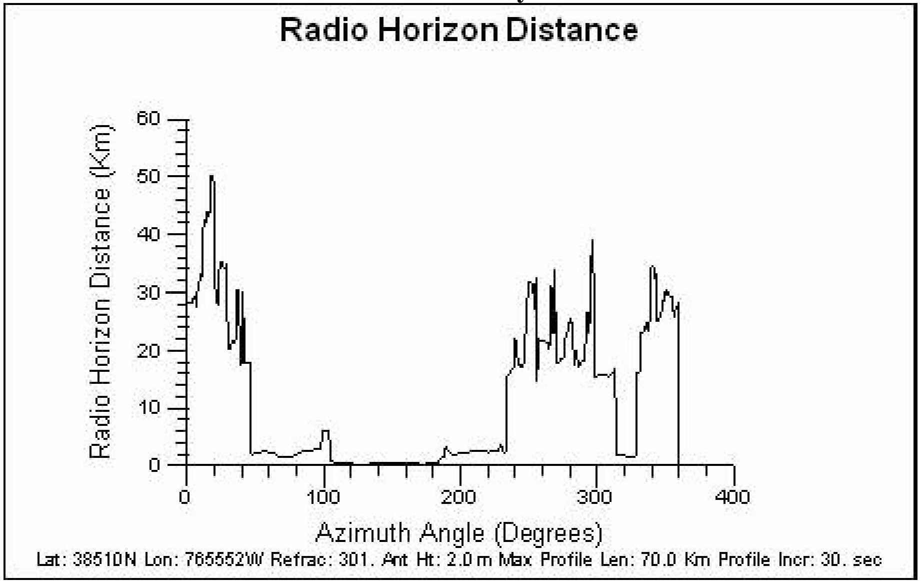
Note 1: SARSAT System uses both RHCP and LHCP
Note 2: SARSAT receivers typically point to the horizon awaiting an oncoming NGSO satellite.

As calculated in Table 3.3.B, if the ATC base station is located more than 85.6 km from the SARSAT receivers, interference is not expected to occur. This is based on the worst case scenario of the main-beam coupling between the SARSAT receive antenna and the ATC base station transmitting antenna using free-space loss. Path profiling (i.e. selecting locations for ATC base stations where main-beam coupling would be less likely to occur) would further reduce this distance.

NTIA has analyzed the same situation and come to the conclusion that an ATC BS within 30 km of a SARSAT station should be coordinated.[145] The approach used by NTIA assumed a number of additional technical factors, including: 15% of the interference budget of the SARSAT system was devoted to ATC and an irregular terrain model (ITM) was used to determine coordination distance.[146] The NTIA analysis shows that a coordination distance of 27 km is necessary. We choose to use a 27 km coordination distance.

The following figures show the distance to the radio-horizon for the two SARSAT stations located in the Washington, D.C. area.[147] While the radio-horizon extends beyond the distance calculated in Table 3.3.B along some azimuths, in general, it is much closer than the maximum interference distance. This should make coordination of the BS and SARSAT operations possible at distances much less than 27 km in many cases.

Figure 3.3.A Distance to Horizon for SARSAT NOAA Facility Suitland MD



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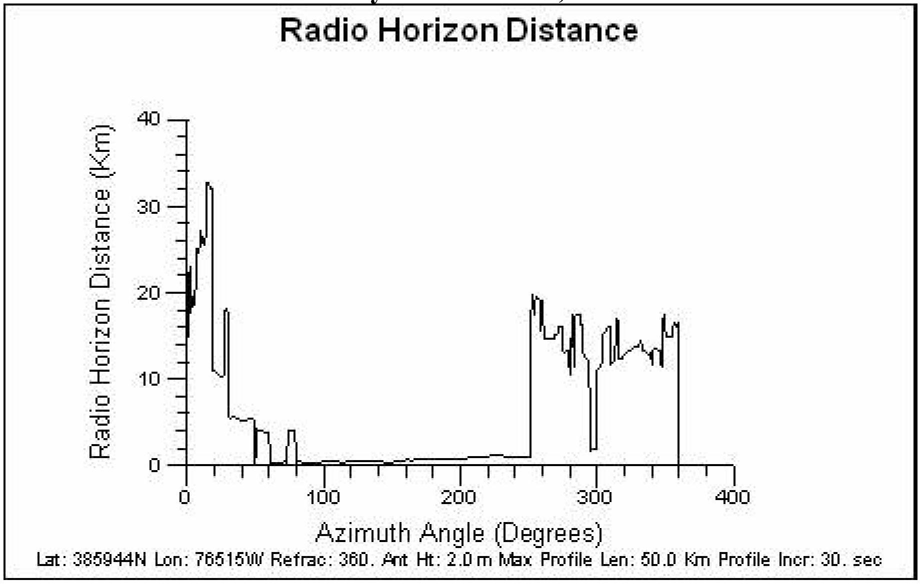
[145] *See* NTIA Nov. 12, 2002 *Ex Parte* Letter, Encl. 5.

[146] The Institute for Telecommunication Science Irregular Terrain Model (ITM). For additional information, *see* NTIA Report 82-100, *A guide to the Use of ITS Irregular Terrain Model in the Area Prediction Mode* (April, 1982).

[147] These figures were generated using the software package "HORIZON" available from the NTIA Microcomputer Spectrum Analysis Models webpage http://ntiacsd.ntia.doc.gov/msam/.

Figure 3.3.B Distance to Horizon for SARSAT Facility NASA GSFC, Greenbelt MD



If any ATC base station is intended to be placed within the maximum interference distance of 27 km from one of the locations listed in Table 3.3.A, the operator should provide the Commission with sufficient information so that the Commission can coordinate the ATC BS with SARSAT operations. This should be done on a case-by-case basis prior to operation to avoid possible unacceptable interference to SARSAT operations.

3.4 Systems Operating Adjacent to the 1626.5-1660.5 MHz Portion of the L-Band

MSV's ATC MTs will transmit to ATC base station receivers in the 1626.5-1660.5 MHz frequency band. Below the 1626.5 MHz band, the Iridium and Globalstar Big LEO systems operate in the 1610-1626.5 MHz band. Big LEO MSS MES emissions are limited by national and international regulations to an EIRP density limit of –15 dBW/4kHz in parts of the band where airborne electronic aids to air navigation are being developed, and –3 dBW/4kHz elsewhere in the band.[148] Additionally, section 25.202(f) of the Commission's rules applies an out-of-band emission mask to Big LEO MSS MES emissions within the 1610-1626.5 MHz band. Given these two parameters, Big LEO MES emissions are limited to out-of-band power densities of (-3-43 =) -46 dBW/4KHz to (-15-43 =) –58 dBW/4kHz within the 1610-1626.5 MHz band.

The peak EIRP of MSV's ATC mobile terminal is 0 dBW with a bandwidth of 200 kHz. These parameters produce an in-band EIRP density of –17 dBW/4kHz. Using the same section 25.202(f) out-of-band emission mask that applies to Big LEO terminals yields a maximum ATC MT emission level of –60 dBW/4kHz in the Big LEO Band. This value is 2 dB lower than the more restrictive then the Big LEO MES out-of-band requirements to protect other Big LEO operations. Out-of-band emissions from the MSV ATC MTs, therefore, should not interfere with Big LEO systems operating in the adjacent spectrum.

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[148] *See* Footnote 5.364 to the ITU Radio Regulations, Article 5, Table of Frequency Allocations; *see also* 47 C.F.R. § 2.106.

3.5 Systems Operating Adjacent to the 1525-1559 MHz Portion of the L-Band

Mobile Aeronautical Telemetry (MAT). Mobile Aeronautical Telemetry (MAT) systems operate below 1525 MHz. The Aerospace & Flight Test Radio Coordinating Council (AFTRCC) is concerned about the potential for interference that MSV ATC base stations could cause to MAT operations adjacent to the L-band. MSV asserts that, under the worst case scenario, there would be no interference to a MAT receiver from an ATC base station if the ATC base station is located at least 0.9 km from the MAT receiver.[149] We have evaluated MSV's calculations and agree with the assumptions and results of MSV's analysis. However, the proper coordination distance for this case should be based on radio line of sight. MSS operators should take all practicable steps to avoid locating ATC base stations within radio line of sight of MAT receive sites in order to protect United States MAT systems consistent with Recommendation ITU-R M.1459. MSS ATC base stations located within radio line of sight of a MAT receiver must be coordinated with AFTRCC for non-Government MAT receivers on a case-by-case basis prior to operation. For government MAT receivers, the licensee will supply sufficient information to the Commission to allow coordination to take place. A listing of current and planned MAT receiver sites can be obtained from AFTRCC for non-Government sites and through the FCC's IRAC Liaison for Government MAT receiver sites.

Global Positioning System (GPS). The Global Positioning System operates above 1559 MHz. MSV demonstrates in its comments that its ATC base stations will be capable of meeting the -70 dBW/MHz and –80 dBW for discrete spurious emissions measured in 700 Hz, which is required of other radio transmitters operating near the spectrum used by GPS.[150] Based on MSV's proposal to operate its ATC base stations with a transmit power of 23 dBW EIRP per sector, and 1.2 MHz of frequency separation between the ATC base station and the GPS band, MSV's equipment manufacturer, Ericsson, is committed to meeting the out-of-band emission attenuation requirements. Based on the information provided by MSV, it appears that MSV's base stations will be capable of meeting the -70 dBW/MHz (and –80 dBW for discrete spurious emissions) out-of-band emission levels in the RNSS allocation as required by other transmitters currently operating in frequency bands adjacent to GPS operations. This conclusion is supported by an *ex parte* agreement that was submitted to the FCC, jointly, by the GPS Industry Council and MSV on July 17, 2002.

The MSV/GPS Industry Council agreement specifies that the MSV ATC base stations will "[u]se filtering to achieve -100 dBW/MHz, or lower" emissions in the [1559-1605 MHz] frequency band. Also, the *ex parte* filing states that the ATC Terminals will "[u]se filtering to achieve -90 dBW/MHz, or lower, in [the] short-term" and will 'migrate to -95 dBW/MHz, or lower, for new terminals in 5 years (from the date MSV service is operational)" for emissions in the [1559-1605 MHz] frequency band. The emission limits contained in the GPS Industry Council/MSV agreement are significantly lower than those currently required for the protection of the GPS L1 signal by other radio frequency transmitters.

One scenario not specifically addressed by the MSV/GPS Industry Council agreement is that of the potential interference to GPS time-base receivers commonly used in cellular networks. These receivers are typically located on the cellular transmit towers and supply timing information to

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[149] MSV Jan. 11, 2002 *Ex Parte* Letter at 29.

[150] *See GMPCS Order,* 7 FCC Rcd at 8936, ¶ 88.

the local phone cell. Because of the possible close proximity of the MSV base station transmit antenna to a cellular time-base receiver of another system, particularly if they are on the same tower, MSV should take necessary steps to avoid causing interference to receive equipment occupying the same tower.

Annex 1 to Appendix C2
MathCad Program for Evaluating Potential Saturation of Airborne MSS Receivers in the L-Band

The following examines an airborne receiver receiving potential interference from a number of ATC base stations. The base stations are distributed randomly over an area visible to the aircraft. The airborne receiver has an omnidirectional antenna of Gac. The base station has a Gbs antenna which is oriented with a angle of theta to the horizon and a random azimuth.

________________________________ some necessary functions

$$\mathrm{dB}(x) := 10 \cdot \log(x) \qquad \mathrm{r2d} := \frac{180}{\pi} \qquad \mathrm{d2r} := \frac{\pi}{180}$$

$$\mathrm{real}(x) := 10^{\left(\frac{x}{10}\right)}$$

$$\mathrm{freq} := 1.550 \qquad \mathrm{iso} := \mathrm{dB}\left[\frac{\left(\frac{0.3}{\mathrm{freq}}\right)^2}{4 \cdot \pi}\right] \qquad \mathrm{iso} = -25.256$$

function atan2(x,y) returns the angle (0 to 360 degrees in radians) given x and y values

```
atan2(x, y) :=
    $\mathrm{ans} \leftarrow \frac{\pi}{2} \cdot \mathrm{sign}(x)$  if  $y = 0$
    $\mathrm{ans} \leftarrow \mathrm{atan}\left(\frac{x}{y}\right)$  otherwise
    $\mathrm{ans} \leftarrow \pi + \mathrm{ans}$  if  $y < 0$
    $\mathrm{ans} \leftarrow 2 \cdot \pi + \mathrm{ans}$  if  $x < 0 \wedge y > 0$
    ans
```

```
$spread\_cir(num, dist) :=$
    $i \leftarrow 0$
    while $i \le num$
        $xa \leftarrow (1.0 - rnd(2.0)) \cdot dist$
        $ya \leftarrow (1.0 - rnd(2.0)) \cdot dist$
        $da \leftarrow \sqrt{ya^2 + xa^2}$
        if $da \le dist$
            $az \leftarrow atan2(xa, ya)$
            $out_{i,0} \leftarrow az$
            $out_{i,1} \leftarrow da$
            $i \leftarrow i + 1$
    $out$
```

Function spread_cir generates random points over a circularly shaped area and returns the distance and azimuth of the point from a central point. Distance is returned in the input units of the argument 'dist'. Az is returned in radians. 'Num" is the number of required randomly located points. This function requires the 'atan2(x,y)' function. The returned array 'spread_cir' is a two column array. The first column (subcript n,0) is the azimuth. The second (subscript n,1) is the distance. The variable 'n;' is the running index.

Base Station Antenna Discrimination Pattern and Aircraft Gain Pattern

Base station parameters

parameter used in defining antenna discrimination pattern

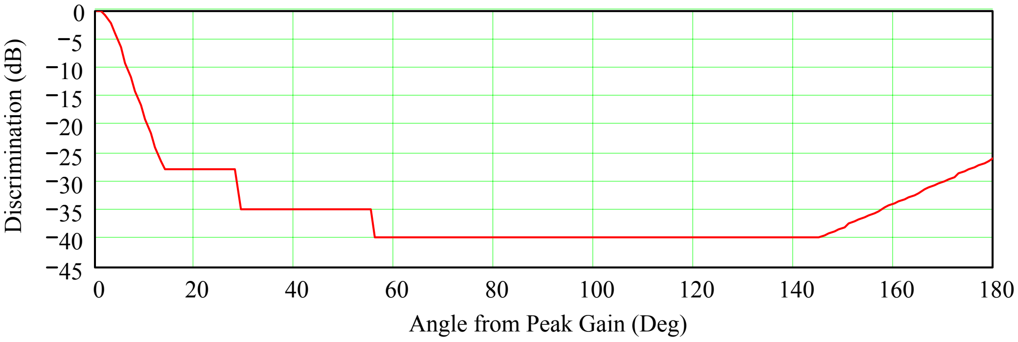
$Go := 12$

$\theta 3 := 107.6\,10^{(-0.1\cdot Go)}$ $\qquad \theta 3 = 6.789$

$$Gbs1(\theta) := \left| \begin{array}{l} g \leftarrow -12\cdot\left(\dfrac{\theta}{\theta 3}\right)^2 \ \text{ if } 0 \le \theta < 4 \\ g \leftarrow -(\theta - 4)\cdot 2.5 - 4.166 \ \text{ if } 4 \le \theta < 13.5 \\ g \leftarrow -28 \ \text{ if } 13.5 \le \theta < 29 \\ g \leftarrow -35 \ \text{ if } 29 \le \theta < 56 \\ g \leftarrow -40 \ \text{ if } 56 \le \theta < 145 \\ g \leftarrow -40 + 14\cdot\dfrac{(\theta - 145)}{35} \ \text{ if } 145 \le \theta \le 180 \\ g \end{array} \right.$$

$Gbs1(0) = 0$

$\theta := 0..\,180$



Tilt angle of base station ant

$tilt := -5$

Aircraft Gain Patterns

$Gac1(\phi) := 0$

Geometric constants and parameters

$\mathrm{Re} := 6378 \cdot 1000$ Earth radius meters

$\mathrm{hbs} := 30$ height of base station antenna in meters

$\mathrm{hac} := \frac{1000}{5280} \cdot 1.609 \cdot 1000$ $\mathrm{hac} = 304.735$ height of aircraft meters

$\zeta := \mathrm{acos}\left(\frac{\mathrm{Re}}{\mathrm{Re} + \mathrm{hbs}}\right)$ Central angle, base station to limb in radians

$\zeta \cdot \mathrm{r2d} = 0.176$ degrees $\zeta \cdot \frac{\mathrm{Re}}{1000} = 19.562$

$\xi := \mathrm{acos}\left(\frac{\mathrm{Re}}{\mathrm{Re} + \mathrm{hac}}\right)$ Central angle, aircraft to limb in radians

$\xi \cdot \mathrm{r2d} = 0.56$ degrees $\xi \cdot \frac{\mathrm{Re}}{1000} = 62.346$

$\mathrm{mdist} := (\zeta + \xi) \cdot \mathrm{Re}$

$\frac{\mathrm{mdist}}{1000} = 81.908$ radius of area in which base stations can be seen by aircraft (km)

$\frac{\mathrm{mdist}}{1.609 \cdot 1000} = 50.906$ miles $(\zeta + \xi) \cdot \mathrm{r2d} = 0.736$

General model parameters

$\mathrm{m} := 1000$ number of base station in view of aircraft

$\mathrm{t} := 100$ number of trials of 'm' base stations

```
atten := for $j \in 0..t$                                          set loop for number of trials (t)
    $cum\_var \leftarrow 0$                                         zero out variable to cumulate answer
    for $i \in 0..m$                                                'for loop' for number base stations in given trial
        $staloc \leftarrow spread\_cir(1, mdist)$                    place BS at random distance 'staloc'(see
                                                                         'spread_cir' function)
        $cent \leftarrow \frac{staloc_{0,1}}{Re}$                   calc. geocentric angle from a/c to staloc (rad)
        $dist \leftarrow \sqrt{(Re+hbs)^2 + (Re+hac)^2 - 2\cdot(Re+hbs)\cdot(Re+hac)\cdot\cos(cent)}$    calc. distance from a/c to base station (m)
        $arg \leftarrow \frac{Re+hac}{dist}\cdot\sin(cent)$         calc. look angle base station ant. to a/c (rad)
                                                                      check for over flow of argument before taking
                                                                      'acos'
        $arg \leftarrow sign(arg)$ if $arg \ge 1.0$
        $bs2ac \leftarrow acos(arg)$
        $bs2ac\_tilt\_deg \leftarrow bs2ac\cdot r2d - tilt$          calc. gain discrimination of base station antenna
        $bsgaindisc \leftarrow Gbs1(|bs2ac\_tilt\_deg|)$               towards a/c taking into account antenna tilt
        $ac2bs \leftarrow \frac{\pi}{2} - bs2ac - cent$             calc. aircraft to base station look angle (ac2bs)
        $ac2bs\_ant \leftarrow \pi - ac2bs$                         assume a/c antenna is looking up and calc.
        $ac2bs\_ant\_deg \leftarrow ac2bs\_ant\cdot r2d$               off-axis angle (ac2bs_ant=180-ac2bs)
        $acgain \leftarrow Gac1(|ac2bs\_ant\_deg|)$                 get gain from a/c to base station (acgain)
        $ggrr \leftarrow bsgaindisc + acgain + dB\left(\frac{1}{4\cdot\pi\cdot dist^2}\right)$    bts to a/c gain disc x ac to bs gain x spreading loss
                                                                      (in dBs)
        $cum\_var \leftarrow cum\_var + real(ggrr)$                 cumulate gains x loss as real values
    $cum_j \leftarrow dB(cum\_var) + iso$                           finished 'for loop' - convert real to dB and add isotropic
cum                                                                 antenna area to get sum of antenna gains and losses
                                                                    for m stations in view of aircraft
```

$$\text{ave} := \text{dB}\left(\frac{1}{t+1}\cdot\sum_{i=0}^{t}\text{real}\left(\text{atten}_i\right)\right)$$

'ave' is the average expected coupling loss between all of the base stations and the aircraft receiver. The aircraft gain, path loss and transmitter discrimination summed across all of the base stations are accounted for. The min and max are the highest and lowest values across all of the trials. Adding the transmit EIRP and other non-geometrically based gains and losses will yield the power received by the aircraft receiver.

$\text{ave} = -105.461$

$\min(\text{atten}) = -105.836$

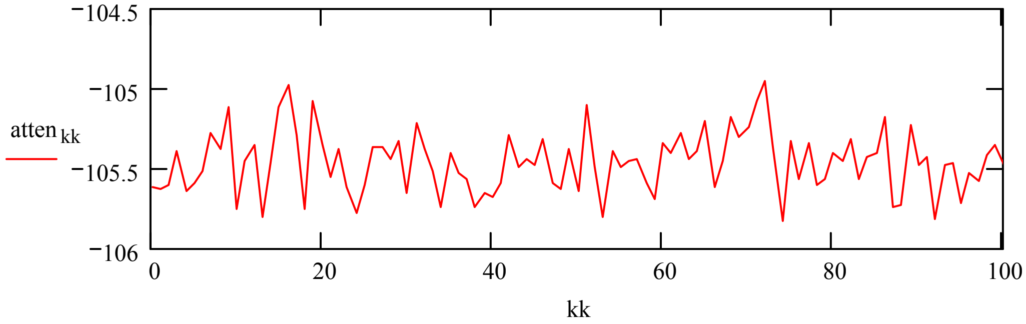
$\max(\text{atten}) = -104.956$

$m = 1\times 10^3$ $\quad$ $\text{hac} = 304.735$

$t = 100$ $\quad$ $\text{hbs} = 30$

$\text{kk} := 0..t$

$\text{mdist}\cdot\frac{1}{1000} = 81.908$ km



atten =

	0
0	-105.617
1	-105.63
2	-105.604
3	-105.399
4	-105.645
5	-105.589
6	-105.522
7	-105.282
8	-105.377
9	-105.122
10	-105.76
11	-105.456
12	-105.358
13	-105.806
14	-105.468

This plot looks at the change in isolation between the aircraft and the base station as a function of the aircraft altitude.

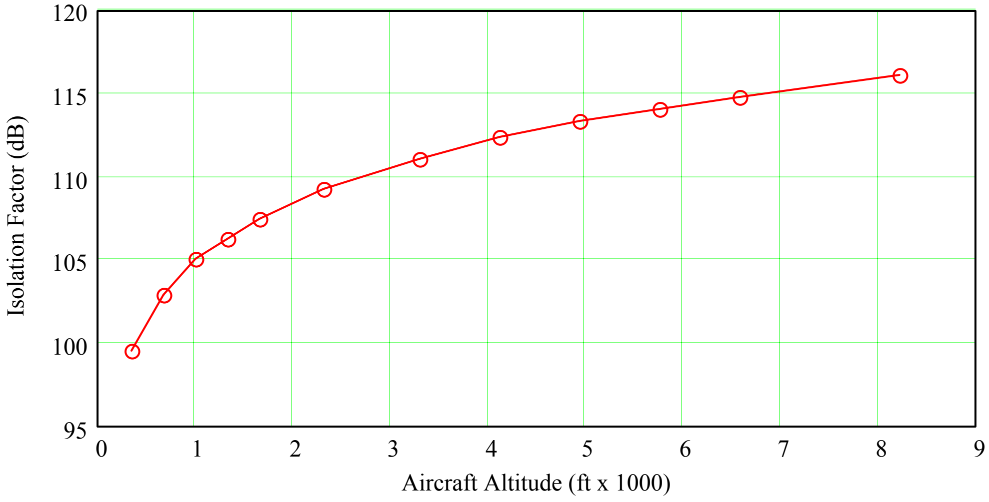
$$hei := \begin{pmatrix} 100 & -99.47 & 0 \\ 200 & -102.87 & 0 \\ 304.7 & -104.99 & 0 \\ 400 & -106.235 & 0 \\ 500 & -107.479 & 0 \\ 700 & -109.191 & 0 \\ 1000 & -111.024 & 0 \\ 1250 & -112.328 & 0 \\ 1500 & -113.282 & 0 \\ 1750 & -114.077 & 0 \\ 2000 & -114.795 & 0 \\ 2500 & -116.062 & 0 \end{pmatrix}$$

$$k := 0..11$$

$$hei_{k,2} := \left(hei_{k,1} - hei_{1,1}\right)$$

$$hei_{k,0} := \frac{hei_{k,0}}{1000}\cdot\frac{1}{1.609}\cdot\frac{5280}{1000}$$

convert altitude to (ft x 1000)



hei =

	0	1	2
0	0.328	-99.47	3.4
1	0.656	-102.87	0
2	1	-104.99	-2.12
3	1.313	-106.235	-3.365
4	1.641	-107.479	-4.609
5	2.297	-109.191	-6.321
6	3.282	-111.024	-8.154
7	4.102	-112.328	-9.458
8	4.922	-113.282	-10.412
9	5.743	-114.077	-11.207
10	6.563	-114.795	-11.925
11	8.204	-116.062	-13.192

APPENDIX C3 – TECHNICAL EVALUATION OF BIG LEO ATC PROPOSALS

1.0 Introduction

This Appendix reviews the potential interference of various scenarios with the respect to Big LEO ATC operations in 1610-1626.5 MHz and 2483.5-2500 MHz Big LEO uplink and downlink bands, respectively. The Appendix describes, in Section 2, the assumptions used in the various analyses contained in this Appendix. Section 3 discusses the intra-system sharing between the two operating Big LEO systems. Finally, Section 4 discusses inter-system sharing between a Big LEO ATC system and other communication systems that could potentially be affected by interference resulting from the ATC operations.

The specific sharing analyses contained in this Appendix are:

Big LEO Uplink Band (1610-1626.5 MHz)

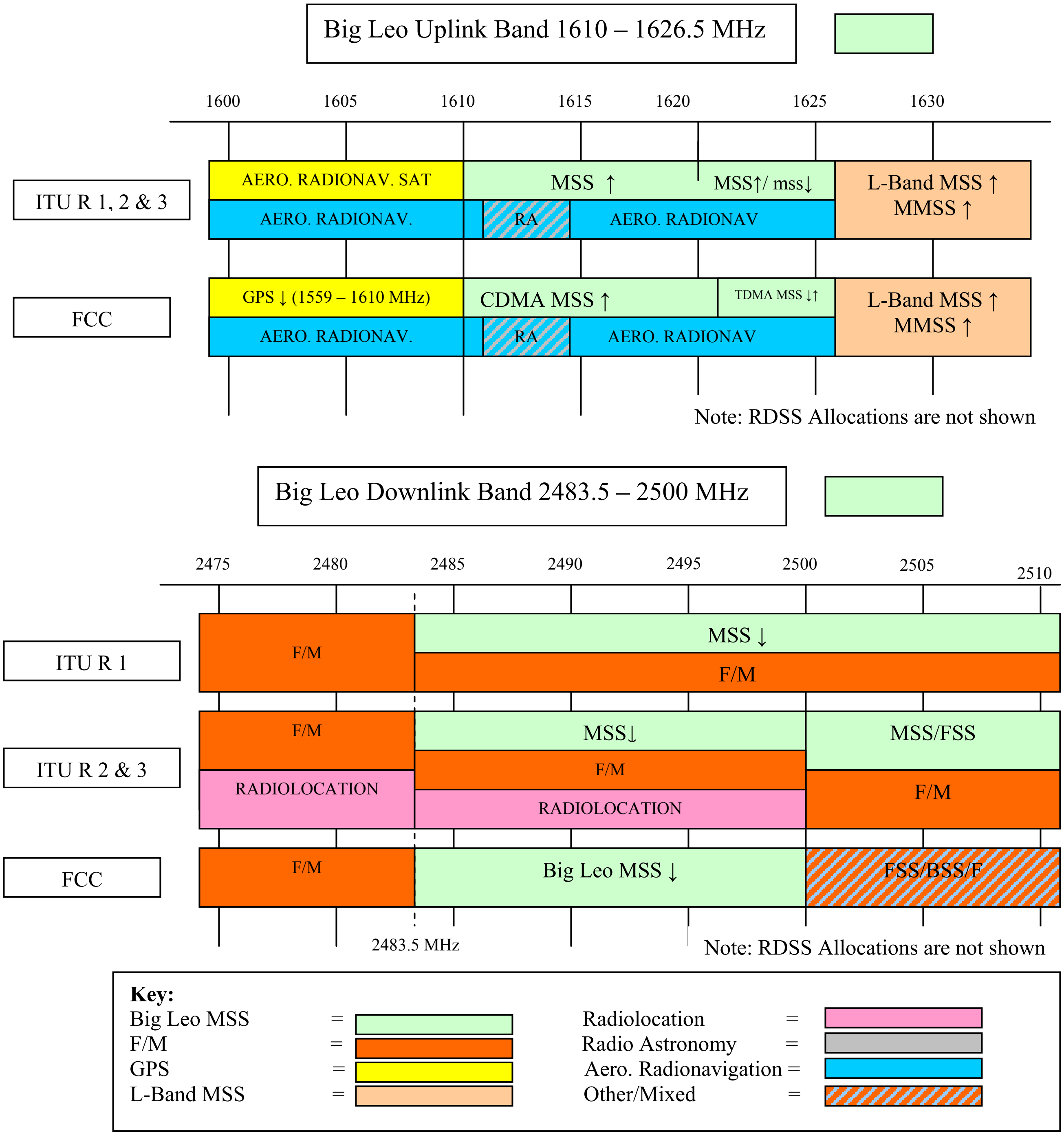
- Limitations on ATC Mobile Terminal (MT) out-of-band emission levels to protect out-of-band, inter-service systems; and
- Limitations on ATC MT out-of-band emission levels to protect out-of-band, intra-service systems.

Big LEO Downlink Band (2483.5-2500 MHz)

- Potential out-of-band interference from Big LEO ATC base stations operating in the downlink band (2483.5-2500 MHz) to ENG channels A8 (2450 – 2467 MHz) and A9 (2467-2483 MHz);
- Potential out-of-band interference from Big LEO ATC base stations operating in the downlink band to fixed and mobile (Part 90 and 101) licensed systems;
- Potential out-of-band Interference from Big LEO ATC base stations operating in the downlink band to ITFS/MMDS (Instructional Television Fixed Services/ Multi-channel Multi-point Distribution Service) above 2500 MHz;
- Potential out-of-band Interference from Big LEO ATC base stations operating in the downlink band to unlicensed 802.11b devices, and
- Potential in-band interference to (grandfathered) BAS, fixed and mobile systems in the 2483.5 – 2500 MHz band.

Figure 1.0.A shows the radio services allocated in the spectrum near the Big LEO uplink and downlink bands from both the ITU and the FCC Allocation Tables.

Figure 1.0.A Current Big LEO Table Allocations



2.0 Assessment of Assumptions used in Technical Analysis

2.1 Out-of-Band Emissions of ATC Operations

Globalstar's ATC system proposal is based on either the IS-95 or the CDMA-2000 standard.[151] Table 2.0.A presents the pertinent characteristics of the IS-95 and CDMA-2000 terrestrial PCS systems.

Table 2.1.A Characteristics of Candidate Big LEO ATC systems

Item	Units	IS-95 Characteristics	CDMA-2000 Characteristics
Mobile Terminal			
EIRP	(dBW)	0.2-1.0	0.1
Bandwidth	(MHz)	1.23	1.25
Out-of-Band Emission Level		>900kHz -42 dBc/30 kHz >1.98 MHz -54 dBc/30 kHz	
Receiver Sensitivity	(dBW)	-134	-134.0
Interference Threshold	(dBW)	-138.9	-140.0
Base Station			
EIRP	(dBW)	32.0	27.0
Antenna Gain	(dBi)	19.0	17.0
Out-of-Band Emission Level		>750 kHz -45 dBc/30 kHz >1.98 MHz -60 dBc/30 kHz	
Receiver Sensitivity	(dBW)	-147.0	-149.0
Interference Threshold	(dBW)	-136.3	-144.0

3.0 Intra-Service Sharing Interference Analysis

3.1 Intra-Service Sharing 1610-1626.5 MHz

Figure 1.0.A shows the allocations in the Big LEO uplink band. The MSS allocation from 1610 MHz to 1621.35 MHz is occupied by Big LEO systems utilizing direct sequence spread spectrum techniques. Globalstar is the only Big LEO system operating in this portion of the MSS uplink band. Therefore, the intra-service considerations are internal to the Globalstar system. Globalstar stated that it would assign separate frequencies to MSS and ATC operations varying the assignments on a timed basis.[152] The ATC services, which would be limited to relatively few cities, could cause co-frequency MSS services to be unavailable in areas of the United States where the satellite beam coverage included a co-frequency ATC city. These restricted frequency MSS areas would vary as satellites move in orbit and the coverage area changes. Globalstar also indicates that dynamically assigning some frequencies to ATC in selected cities while assigning different frequencies to the MSS operations will reduce the loss of the MSS coverage area. They

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[151] Globalstar May 29, 2002 *Ex Parte* Letter, Attach. A at 2-3.

[152] *See* Globalstar June 27, 2002 *Ex Parte* Letter at 2.

also indicate that MSS operators could reserve some spectrum for MSS-only operations. Thus the inter-service sharing is managed within the Globalstar system.

The 1621.35 MHz to 1626.5 MHz band is occupied by Big LEO systems using TDMA transmission techniques. Iridium is the only Big LEO system occupying this band. At the time the *Big LEO Service Rules Order* was released, the Commission declined to address comprehensively the issue of emission limits between MSS systems due to the early development of a regulatory structure conductive to the rapid and successful deployment of the Big LEO's services.[153] The Commission did, however, adopt a band arrangement to accommodate these and additional Big LEO MSS systems, as well as maximum MT EIRP levels and out-of-band emission levels.[154] The same band plan, power and out-of-band emission levels for MSS ATC will provide for continued MSS use of the 1610-1626.5 MHz band with ATC operations.

3.2 Intra-Service Sharing 2483.5-2500 MHz

The MSS downlink allocation from 2485.3 MHz – 2500 MHz is occupied solely by Globalstar. Therefore, the intra-service considerations are internal to the Globalstar system.

4.0 Inter-Service Sharing Interference Analysis

4.1 Inter-Service Sharing 1610-1626.5 MHz

4.1.1 Limitations on ATC MT Out-Of-Band Emission Levels to Protect Adjacent Band Systems

Global Positioning System (GPS). Out-of-band emission levels for ATC MT transmitters are required to protect Radionavigation Satellite Service (RNSS) systems such as GPS and L-band Mobile Satellite Service (MSS) systems such as Inmarsat from potentially unacceptable interference. This specific interference issue has been resolved for Big LEO MSS systems that have MSS Mobile Earth Station (MES) that operate in accordance with Recommendation in ITU-R M.1343.[155] ITU-R M.1343 recommends the maximum unwanted emissions outside the band 1610-1626.5 MHz for an MSS MES. An excerpt from ITU-R M.1343 is provided below in Table 4.1.1.A.

Table 4.1.1.A Out-of-Band Emissions into GPS Band

Frequency (MHz)	Carrier-on	
	EIRP (dBW)	Measurement Bandwidth
1590-1605	-70[156]	1 MHz
1605-1610	-70 at 1605 MHz, linearly	1 MHz

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[153] *Big LEO Service Rules Order*, 9 FCC Rcd at 5962, ¶ 63.

[154] *See* 47 C.F.R. §§ 2.106, 25.202(f).

[155] International Telecommunications Union, *Essential Technical Requirements of Mobile Earth Stations for Global Non-Geostationary Mobile Satellite Service Systems in the Band 1-3 GHz*, Recommendation ITU-R M.1343 (1997).

[156] This value is subject to further study in ITU-R according to Recommendation ITU-R M.1343.

	interpolated in dB/MHz to -10 at 1610 MHz[157]	
1628.5-1631.5	-45	1 MHz
1631.5-1636.5	-50	1 MHz
1636.5-1646.5	-55	1 MHz
1646.5-1666.5	-60	1 MHz

The proposed Big LEO ATC MTs are capable of meeting the recommended out-of-band emission levels of the Big LEO MSS systems contained in Table 4.1.1.A.[158] The Commission requires Big LEO MSS systems to meet these same levels in order to protect inter-service operations in adjacent frequency bands.[159] The same out-of-band emission levels should apply to Big LEO ATC MTs to ensure the same level of protection to these inter-service systems.

Radioastronomy Service (RAS). Additionally, the Commission in its 1996 Big LEO MO&O ruled that harmful interference shall not be caused to stations of the radio astronomy service using the band 1610.6-1613.8 MHz by stations of radiodetermination satellite[160] and mobile-satellite services.[161] The Commission's rules require that mobile earth stations have position-determination capabilities[162] to ensure compliance with out-of-band emission limits for MSS MES in areas around known RAS sites. The limits require that MES licensed in the 1610-1626.5 MHz band produce power flux densities that do not exceed, at the RAS, the power flux density that would be produced by a MES operating in the 1610.6-1613.8 MHz bands at the edge of the site's protection zone.[163] In order to continue protection to RAS observations in this frequency band, the MSS ATC network should be capable of providing the same level of protection. Specifically, the MSS ATC systems could be required to meet the same out-of-band emission and position determination requirements as Big LEO MSS systems to respect the fixed-radius

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[157] According to the ITU, appropriate protection of GNSS needs to be considered, recognizing the current operation and phased transition of the GLONASS system into the new frequency plan. The Russian Federation states that the level of -70 dBW/MHz shall be used to provide protection of GLONASS receiver operations and that a level of -37 dBW/MHz at 1 610 MHz, linearly interpolated to –70 dBW/MHz at 1 607.5 MHz, is sufficient to protect GLONASS wideband operations in the final GLONASS frequency plan.

[158] In the technical statement filed by Globalstar on 5/29/02, Globalstar stated its ATC system has typical out of channel EIRP of -42 dBW/30khz with 1.98 MHz offset, which is -26 dBW/1MHz.

[159] *See GMPCS Report and Order*, 17 FCC Rcd at 8927-28, ¶¶ 60-63.

[160] There is no radio determination satellite system currently operating in the 1.6 GHz band.

[161] *Big LEO Memorandum Opinion and Order*, 11 FCC Rcd at 12866, ¶ 15.

[162] Position-determination equipment allows a mobile terminal to calculate, based on signals received from multiple satellite or ground-based stations, its geographic location and altitude. This information can then be used to determine if the mobile terminal is within the protected radio astronomy zone, and, if it is, to avoid transmitting signals that would cause harmful interference. In addition to GPS, the satellite-based global position system, and LORAN, a terrestrially based position determination system, Big LEO satellites may also, depending on system design, act as a source of position determination information for mobile terminals.

[163] For MSS operations outside of the United States, the stations will observe limits set by the ITU RR Article 5.364.

protection zones for radio astronomy sites listed in section 25.213 of the Commission's rules and not operate within those zones during periods of radioastronomy observations. This would significantly mitigate any potential interference caused to the RAS from MSS ATC MT operations.

4.2 Inter-Service Sharing 2483.5-2500 MHz

4.2.1 Potential Interference from Big LEO Base Stations to Fixed and Mobile Stations Operating in the 2483.5-2500 MHz Band

Over 700 fixed terrestrial stations, including temporary fixed (transportable) stations, were licensed and operating in the United States in the 2483.5-2500 MHz band as of 1994.[164] These stations are primarily used as links in microwave relay systems serving petroleum companies and as broadcast auxiliary links. Since 1985, however, the Commission has prohibited any further terrestrial licensing in this band but has permitted the existing stations licensed as of July 25, 1985 to be "grandfathered" in the 2483.5-2500 MHz band subject only to license renewal.[165] In the *Big LEO Report and Order,* the Commission recognized that mutual interference was possible between the fixed and mobile systems and the MSS mobile earth terminal receivers, on the one hand, and the satellite downlinks operating in excess of the prescribed pfd levels and the fixed and mobile receivers on the other hand.[166] In the *RDSS Allocation Order*, we recognized that fixed and temporary-fixed operations are unlikely to pose a serious interference threat to RDSS.[167] However, we acknowledged that coordination would be somewhat more difficult when temporary-fixed stations are involved since RDSS licensees would not have exact information regarding the location of these stations. Therefore, we required temporary-fixed licensees in this band to notify RDSS licensees directly whenever the station is moved to a new location. We also recognized that a similar interference environment is present with MSS operations. Consequently, we modified the Commission's rules to extend the notification requirement for grandfathered temporary-fixed licensees to MSS licensees as well as RDSS licensees.[168]

The operation of ATC base stations in the 2483.5-2500 MHz band could potentially cause interference to the grandfathered fixed and temporary-fixed stations in this band. Additionally, there is a potential for interference from the grandfathered fixed and temporary-fixed stations to

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[164] *Big LEO Service Rules Order*, 9 FCC Rcd at 5992, ¶ 145.

[165] *Allocating Spectrum for and Establishing Other Rules and Policies Pertaining to a Radiodetermination Satellite Service*, 50 Fed. Reg. 39101, 39104, ¶ 20 (1985) (*RDSS Allocation Order*); *see also* 47 C.F.R. §§ 90.20(c)(3)(73), 90.35 (c)(74), 90.103(b)(9) and 101.147(f)(2).

[166] *Big LEO Service Rules Order*, 9 FCC Rcd at 5992, ¶ 146.

[167] *RDSS Allocation Order,* 50 Fed. Reg. at 39104, ¶¶18-20.

[168] Under 47 C.F.R. § 101.4(a), all systems subject to parts 21 and 94 as of July 31, 1996 that are licensed or which are proposed in an application on file as of July 31, 1996 are subject to the requirements under part 94 as contained in the Code of Federal Regulations edition revised as of October 1, 1995 and amended in the Federal Register through July 31, 1669, as applicable, indefinitely. *See* 47 C.F.R § 94.61(b)(4) (1995). Note that 47 C.F.R. § 94.61(b)(4) (Oct. 1, 1995) states that grandfathered temporary fixed licensees are required to notify directly each RDSS and MSS licensees concerning present and proposed locations of operations.

the ATC MTs. With the rules mentioned in the previous paragraph requiring the MSS operators to be notified of any move of a temporary-fixed station, we find that all of the information is available to the MSS operators to coordinate their base stations. We therefore require the MSS ATC operator to coordinate the placement of its base stations with the grandfathered fixed and temporary-fixed stations in this band.

4.2.2 Potential Out-Of-Band Interference from Big LEO ATC Base Stations Below the MSS Downlink Band (2483.5-2500 MHz)

Electronic News Gathering (ENG) Channels A8 (2450 – 2467 MHz) and A9 (2467-2483 MHz). The Society of the Broadcast Engineers (SBE) commented that MSS ATC base stations will cause out-of-band interference and brute force overload to ENG equipment operating in TV BAS ENG Channels A8 and A9 in the 2483.5-2500 MHz band.[169] Currently, 405 TV BAS licenses are issued nationally in the range 2450 MHz to 2483 MHz. There are 87 licensed facilities used for TV inter-city relay, 297 TV pickup licenses, 19 TV studio transmitter links, and 2 TV translator relay licenses. SBE also claims that ENG channel A10 (2483-2500) is operating at the same frequency as the Big LEO space-to-earth (downlink) component. However, our records indicate that there are no grandfathered BAS facilities licensed in the 2483.5 – 2500 MHz Band. However, because ENG did, at one time, operate on Channel A10, it is possible that equipment exists that has front end filters that do not isolate the ENG receiver from transmissions in the 2483.5-2500 MHz band. This would constitute a co-frequency situation as discussed in Section 4.2.1. This Section is limited to potential interference to ENG from ATC base stations out-of-band interference.

The proposed Big LEO ATC base station has a typical in-band transmitter power of 20 W.[170] Furthermore, the proposed out of channel emission for the ATC base station is approximately -45 dBc with frequency offset between 750 KHz and 1.98 MHz from the center; and -60 dBc with frequency offset 1.98 MHz or more. In areas of frequency congestion, the BAS receive stations operating in the 1990-2110 MHz band are required to use Category A antennas, which have 3-dB beam widths of 5 degrees and minimum front-to-back ratios of 38 dB.[171] An antenna with a beam width of 5 degrees would have a gain of approximately 30 dBi. It is assumed that stations operating just below 2485.3 MHz would use similar equipment. The BAS receiver is also assumed to have a sensitivity of -86 dBm and that a 10 dB D/U ratio is acceptable in this adjacent band situation.[172]

Table 4.2.1.A calculates the required separation distance to provide protection to a BAS receiver under two conditions:

- main-beam to main-beam coupling between the ATC base station transmitter and the BAS receiver with a frequency separation of 0.75 MHz, and
- main-beam coupling between the ATC base station transmitter and the back-lobe of a BAS receiver with a frequency separation of 2.0 MHz.

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[169] SBE Comments at 10.

[170] Globalstar May 29, 2002 *Ex Parte* Letter at 3.

[171] *See* 47 C.F.R. § 74.641.

[172] The D/U ratio is taken from on SBE's *Ex Parte* comments filed in ET docket 98-142, August 7, 2001.

Table 4.2.1.A calculates the out-of-band emission from the base station and the interference threshold for the BAS station. The difference between the two values is the required isolation that must exist between the transmitter and receiver to prevent interference from occurring. Table 4.2.1.A uses free space propagation. In urban environments, more sophisticated propagation models would probably identify greater path loss and the corresponding reduction in the required separation distance between the base station and BAS receiver. However, since the free-space model is the worst-case model, we take the more conservative approach in our analysis.

The results of Table 4.2.1.A show that under main-beam to main-beam coupling conditions a required separation distance of more then 4 km can result. The Table also indicates that it may be possible to have a very small separation distance by situating the base station in the back lobe of a fixed BAS antenna and/or incorporating some frequency separation between the BAS channel A09 and the base station transmit frequency.

Table 4.2.1.A BAS versus Big LEO ATC Interference Calculation

Item	Units	Main-Beam	Back-Lobe
		Value	Value
IS-95 System			
Frequency	(GHz)	2.483	2.483
ATC Emission Bandwidth	(MHz)	1.23	1.23
BAS Channel Bandwidth	(MHz)	16.5	16.5
ATC Transmit Power	(W)	20.0	20.0
ATC Transmit Gain	(dBi)	19.0	19.0
ATC EIRP	(dBW)	32.0	32.0
Frequency Separation	(MHz)	0.75	2.0
OOB Reduction	(dBc)	-45.0	-60.0
OOB Emission	(dBW)	-13.0	-28.0
BAS Receiver			
Assumed Sensitivity	(dBm)	-86.0	-86
Required D/U	(dB)	10.0	10.0
Receive Antenna Gain	(dBi)	30.0	-8.0
Area of Isotropic Antenna	(dBm^2)	-29.3	-29.3
Interference Threshold @ Antenna	(dBW/m^2)	-96.7	-58.7
OOB Emission (From Above)	(dBW)	-13.0	-28.0
Required Isolation	(dBm^2)	83.7	30.7
Required Distance (Free Space Loss)	(km)	4.3	0.01

From a spectrum efficiency standpoint, Big LEO ATC operators should implement the least amount of frequency offset necessary to avoid causing unacceptable interference to BAS receivers. It appears from our analysis that coordination of the ATC base stations to protect BAS operations in Channel A09 is possible.

Wireless Services in 2450-2483.5 MHz Band. The FCC actively licenses several services in the 2450-2483.5 MHz band allocated for shared fixed, base, or mobile use under Part 90 (Public

Safety Pool, Industrial/Business Pool, and Radiolocation Service) and Part 101 (Fixed Microwave Service) in addition to Part 74 (Television Broadcast Auxiliary Service). Licenses in this band are used significantly by television stations that operate ground-based and airborne video equipment and also by public safety agencies that are increasingly using the band for live airborne video and for other public safety functions requiring video links. The analysis of the separation distances for BAS protection versus Big LEO ATC base stations presented earlier in this section would pertain directly to the BAS uses licensed under Part 74 to the extent that these Part 90 and Part 101 uses are similar to Part 74. Part 74 and 101 users coordinate their use of the band. Some of these uses are known to be lower power video links. The impact of the ATC base stations on such links could be examined if license information were available in a prior coordination process. Part 90 users are not required to coordinate, although the FCC encourages their participation in a collaborative coordination effort. ATC operators will be required to take measures to protect against all types of interference to the existing users in this shared band.

Unlicensed 802.11b Devices. Although Industrial, Scientific and Medical (ISM) equipment is not subject to any protection from current MSS downlink operations, our research indicates that most 802.11b manufacturers build out-of-band signal rejection features into their hardware. Specifically, in the United States, 802.11b devices operate on channel frequencies ranging from 2412 MHz to 2462 MHz. Lucent Technologies, for example, has also shown in a laboratory test conducted in 1998 that its WaveLAN wireless card can reject up to 35dB when an interfering channel is 25 MHz away.[173] Due to the location the upper band edges of unlicensed 802.11b devices (i.e., 2462 MHz), unlicensed 802.11b devices operating in the United States should have enough signal rejection capability to reject Big LEO ATC base station transmissions.

4.2.3 Potential Out-Of-Band Interference from Big LEO ATC Base Stations Operating Above the MSS Downlink Band (2483.5-2500 MHz)

Instructional Television Fixed Services/Multi-Channel Multi-point Distribution Service (ITFS/MMDS). SBE indicated that there is a potential for ATC transmissions to interfere with ITFS/MMDS receivers operating above 2500 MHz.[174] In order to calculate the required separation distance between Big LEO ATC transmitters and an ITFS/MMDS receiver operating in the adjacent frequency band, the maximum undesired ATC power flux density that would cause interference to a ITFS/MMDS receiver is first determined. Next, the distance between the ATC transmitter and the ITFS/MMDS receiver is calculated at the point where the received power flux density at the ITFS/MMDS receiver is equal to or less than the level that would cause it unacceptable interference. According to the proposed base station data provided by Globalstar, ATC base stations would have a maximum out-of-band EIRP of -40 dBW.[175] The maximum undesired signal power flux density for an ITFS/MMDS station is -129 dBW/m^2 for a 1.25 MHz interfering signal.[176] The minimum required separation distance between an ITFS/MMDS receiver and a Big LEO ATC base station can be calculated by using the following formula:

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[173] WaveLAN Technical Bulletin 003/A, Lucent Technologies, (Nov. 1998).

[174] SBE Comments at 10.

[175] *See Interim Report on the Spectrum Study of the 2500-2690 MHz Band, supra,* at A60 n.2. Typical out-of-band EIRP for an IS-95 system, the alternative CDMA2000 mentioned by Globalstar is expected to have a lower out-of-band emission. Therefore, -40 dBW can be used as the worst case scenario.

[176] The bandwidth here is typical for an IS-95/CDMA2000 system.

Minimum required separation distance = $\sqrt{\frac{EIRP}{PowerFlux * 4 * \pi}}$, where the Power Flux has a reference bandwidth of 1.25 MHz.

The maximum separation distance between an ATC base station and an ITFS/MMDS receiver necessary to avoid adjacent channel interference is 8 km (5 miles) assuming that the ITFS/MMDS receiver is operating directly adjacent to 2500 MHz. The ITFS/MMDS receivers can reject up to 40 dB/MHz according to measurements conducted by the FCC laboratory.[177] Table 4.2.2.A and Figure 4.2.2.A evaluate the required separation distance as a function of the proposed ATC frequency assignments.

Table 4.2.3.A ITFS/MMDS Typical Calculation of Required Separation Distance for a Specific Frequency Separation

Item	Units	Value
Frequency	(GHz)	2.5
Bandwidth	(MHz)	1.23
EIRP	(dBW)	-40.0
Frequency Offset	(MHz)	0.5
ITFS Roll-Off	(dB/MHz)	40.0
Calculated Roll-Off	(dB)	20.0
Effective EIRP (Including Roll-Off)	(dBW)	-60.0
Interference Threshold	(dBW/m^2 in 1.25 MHz)	-129.0
Separation Distance	(km)	0.80
Separation Distance	(miles)	0.49

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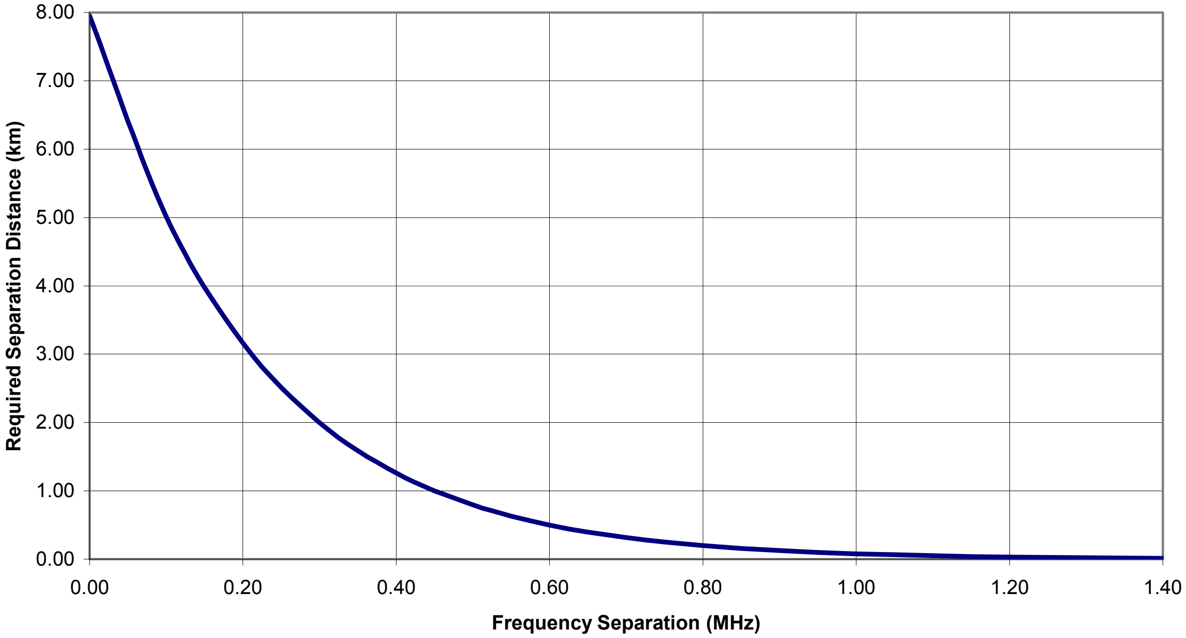
[177] *Spectrum Study of the 2500-2690 MHz Band: The Potential for Accommodating Third Generation Mobile Systems*, Final Report, App. 5.2 (rel., March 30, 2001), *available at* <http://www.fcc.gov/3G/3gfinalreport.doc> (last visited, Feb. 4, 2003) (*Final Report on the Spectrum Study of the 2500-2690 MHz Band*).

Figure 4.2.3.A ITFS/MMDS Required Separation Distance versus Frequency Separation



It appears from our analysis that ATC operations on frequency assignments below 2498 MHz would not cause unacceptable interference to ITFS/MDS receivers in the adjacent frequency band. As with the TV BAS evaluation, this analysis assumes that the ITFS/MDS receiver is in direct line of sight of the Big LEO base station transmitter and there is no additional attenuation of the interfering transmission. Use of a propagation model that takes into account the effects of an urban environment in this frequency range would likely produce a smaller separation distance.