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" 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 smngent 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 Pane* Letter at 2.

[14] 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 (tiled Jan. 15,2003).

[35] *See* 47 C.F.R. § 24.238(a)

[36] ***See Amendment of rhe 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 Pane*** 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."

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

[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.

[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 Pan 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.

[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 Facto?'	(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''	(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.

[49] *Id.* at 19.

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

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

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"	(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

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

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

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

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

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

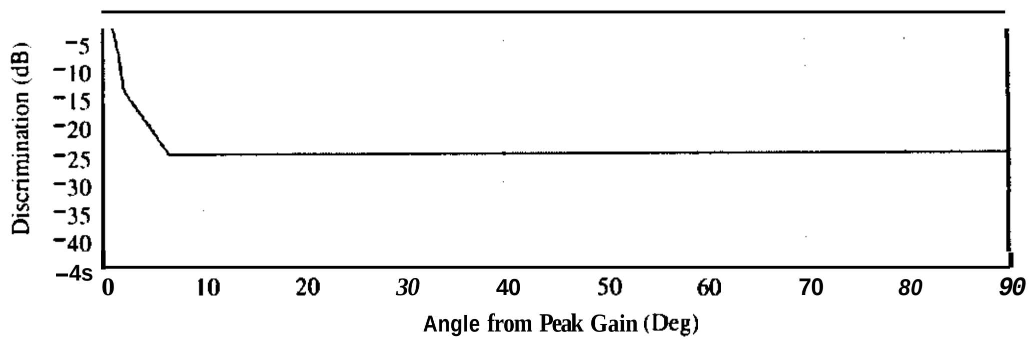
$freq = 2.183$

model parameters________________

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

$$atan2(x,y) := \begin{array}{|l} ans \leftarrow \frac{\pi}{2} \cdot sign(x) \text{ if } y = 0 \\ ans \leftarrow atan\left(\frac{x}{y}\right) \text{ otherwise} \\ ans \leftarrow \pi + ans \text{ if } y < 0 \\ ans \leftarrow 2 \cdot \pi + ans \text{ if } x < 0 \wedge y > 0 \\ ans \end{array}$$

θ := 0.. 900



tilt := -2.5   Tilt angle of base station antenna

EIRP := Po + Go   Base station mainbeam EIRP

EIRPm := EIRP + 30   Base station EIRP in dBm

Aircraft Gain Patterns

Gac(ϕ) := 0   Omnidirectional constant gain from Boeing

limit := -50   Receiver Saturation Level in dBm from Boeing

Geometric constants and parameters

Re := 6378·1000 Earth radius meters

hbs := 30   height of base station antenna in meters

hac_ft := 500   height of aircraft in ft

```
spread_cir(num, dist) := | i ← 0
                         | while i ≤ num
                         |   | xa ← (1.0 – rnd(2.0))·dist
                         |   | ya ← (1.0– rnd(2.0))·dist
                         |   | da ← √(ya^2 + xa^2)
                         |   | if da 5 dist
                         |   |   | az ← atan2(xa, ya)
                         |   |   | DUI_{i,0} ← az
                         |   |   | DUI_{I,I} ← da
                         |   |   | i ← i + I
                         | 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.

$$e3 := 107.6\,10^{(-0.1\cdot Go)}$$

$$Gbs2(\theta) := \begin{cases} g \leftarrow -Go\cdot\left(\frac{|\theta|}{\theta 3}\right)^2 & \text{if } 0 \le |\theta| < 1.935 \\ g \leftarrow -(|\theta| - 4)\cdot 2.5 - 19 & \text{if } 1.935 \le |\theta| < 6.4 \\ g \leftarrow -25 & \text{otherwise} \\ g \end{cases}$$

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.

margin := for $j \in 0..t$	set loop for number of trials (t)
sum_var ← 0	zero out variable to cumulate answer
for $i \in 0..m$	'for loop' for number base stations in given trial
staloc ← spread_cir(1, mdist)	place BS at random distance 'staloc' (see 'spread–cir' function)
$cent \leftarrow \dfrac{staloc_{0,1}}{Re}$	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)
$arg \leftarrow \dfrac{Re + hac}{dist}\cdot\sin(cent)$	calc. look angle base station ant. to a/c (rad) check for over flow of argument before taking 'acos'
arg ← sign(arg) if arg ≥ 1.0	
bs2ac ← acos(arg)	
bs2ac_tilt_deg ← bs2ac·r2d − tilt	calc. gain discrimination of base station antenna towards a/c taking into account antenna tilt
bsgaindisc ← Gbs2(|bs2ac_tilt_deg|)	
$ac2bs \leftarrow \dfrac{\pi}{2} - bs2ac - cent$	calc. aircraft to base station look angle (ac2bs)
ac2bs_ant ← π − ac2bs	assume a/c antenna is looking up and calc. off-axis angle (ac2bs_ant=180-ac2bs)
ac2bs_ant_deg ← ac2bs_ant·r2d	
acgain ← Gac(|ac2bs_ant_deg|)	get gain from a/c to base station (acgain)
$ggrr \leftarrow bsgaindisc + acgain + dB\left(\dfrac{1}{4\cdot\pi\cdot dist^2}\right)$	bts to a/c gain disc x ac to bs gain x spreading loss (in dBs)
cum–var ← cum–var + real(ggrr)	cumulate gains x loss as real values
$sum_j \leftarrow -(dB(cum\_var) + iso + EIRPm - limit)$	finished 'for loop' - convert real to dB and add 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.
sum	

$hac := \frac{hac-ft}{5280} \cdot 1.609 \, 1000$ $\quad hac = 152.367$ **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** $\quad \zeta \cdot \frac{Re}{1000} = 19.562$

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

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

$mdist := (\zeta \; t \; \xi) \cdot Re$

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

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

General model parameters

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

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

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

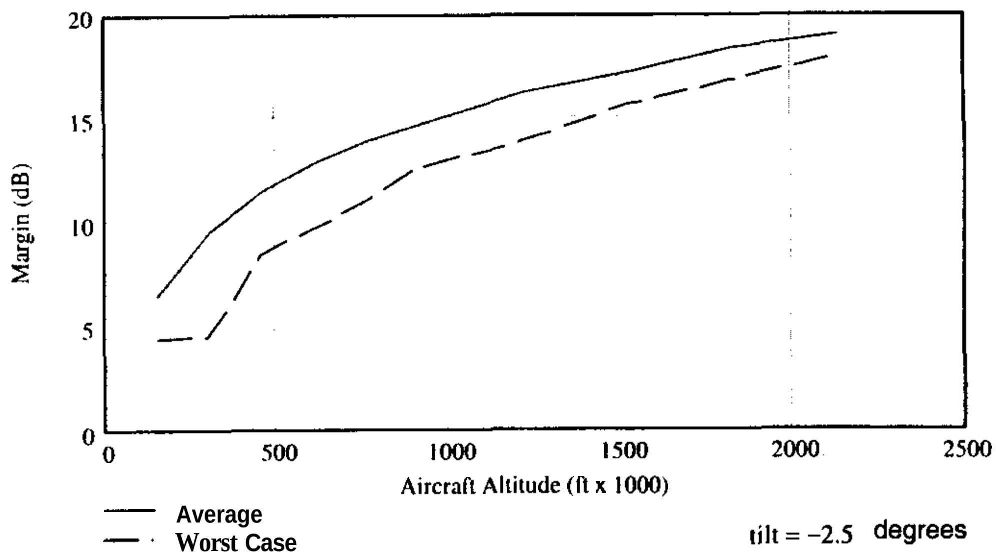
$k := 0.9$

Tilt Angle -2.5 Degrees

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

convert altitude to (ft x 1000)

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



$tilt = -2.5$ degrees

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

ave = 6.594

'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.

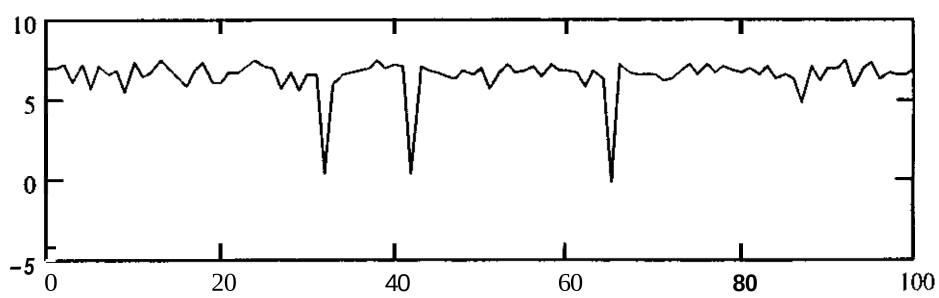
min(margin) = −0.166

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

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 Analvses 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" 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

[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.

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 pane* 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 pans: 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

polarized receiver." 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?' 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 *Pane* Letter at 2-8

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

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

[60] Julius Goldhirsh & Wolfhard Vogel. ***Handbook of Propagation Effects for Vehicular arid 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 Pane*** Letter at 4.

Figure 1.2.2.B: Handbook Figure 10-5

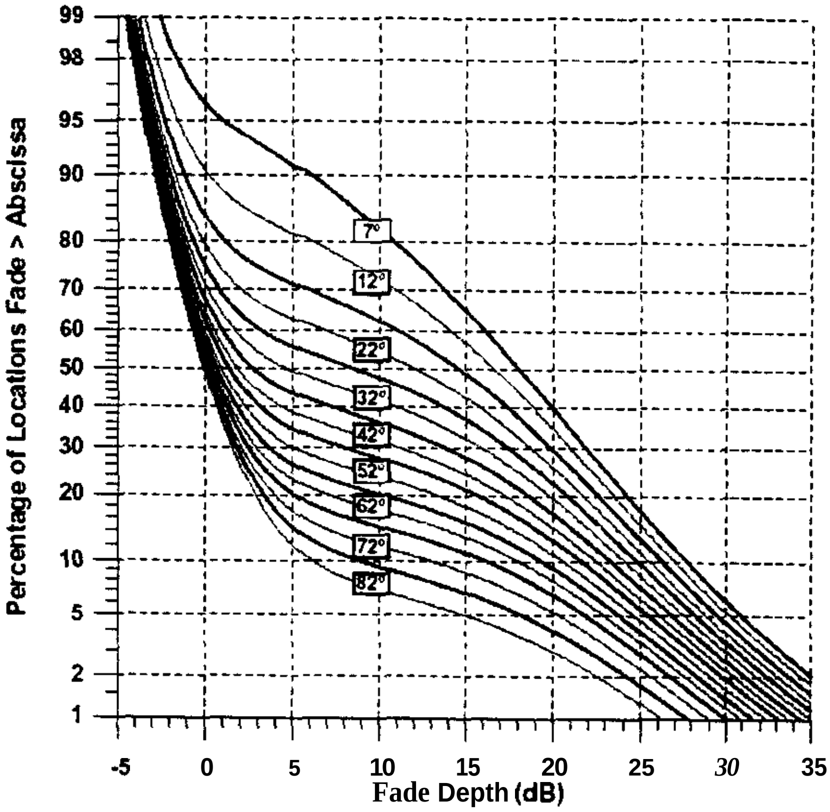
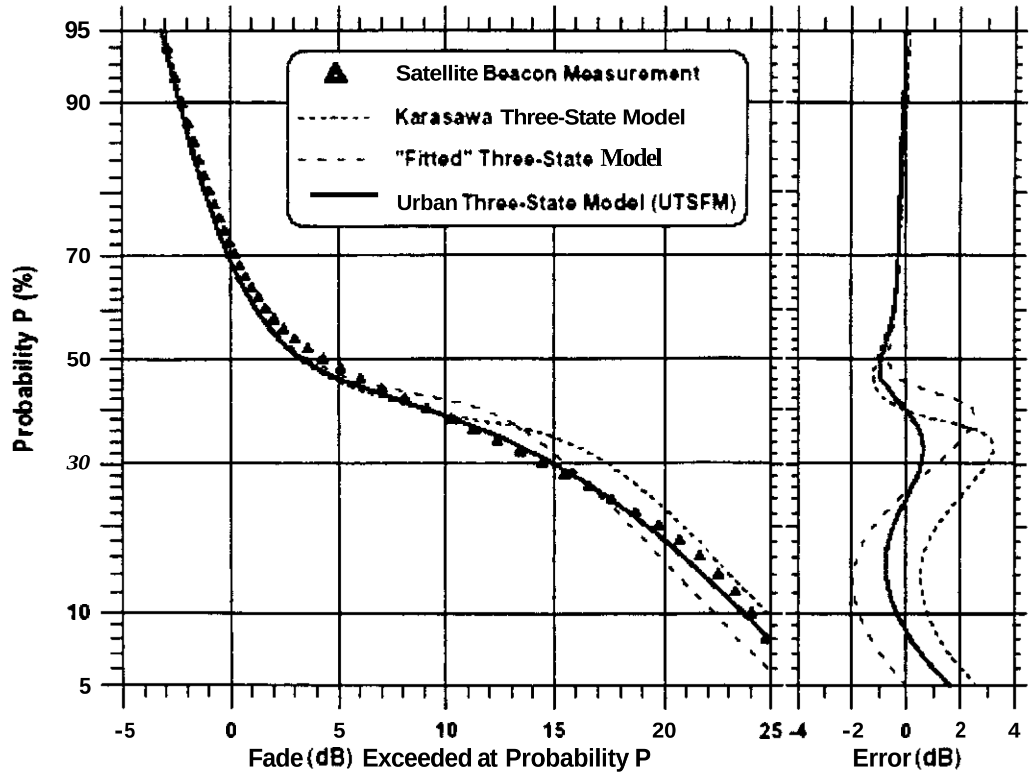


Figure 1.2.2.C shows the expected difference in attenuation, due to blockage, as a function of satellite elevation angle for the *50"* percentile. The data used in Figure 1.2.2.C is directly derived from Figure 1.2.2.B. Figure 1.2.2.C indicates that the blockage factor increases significantly as the 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.

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 12.2.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 vaned.

Table 1.23.A: Elevation Angles to Various Cities as seen from Operating L-band Satellites

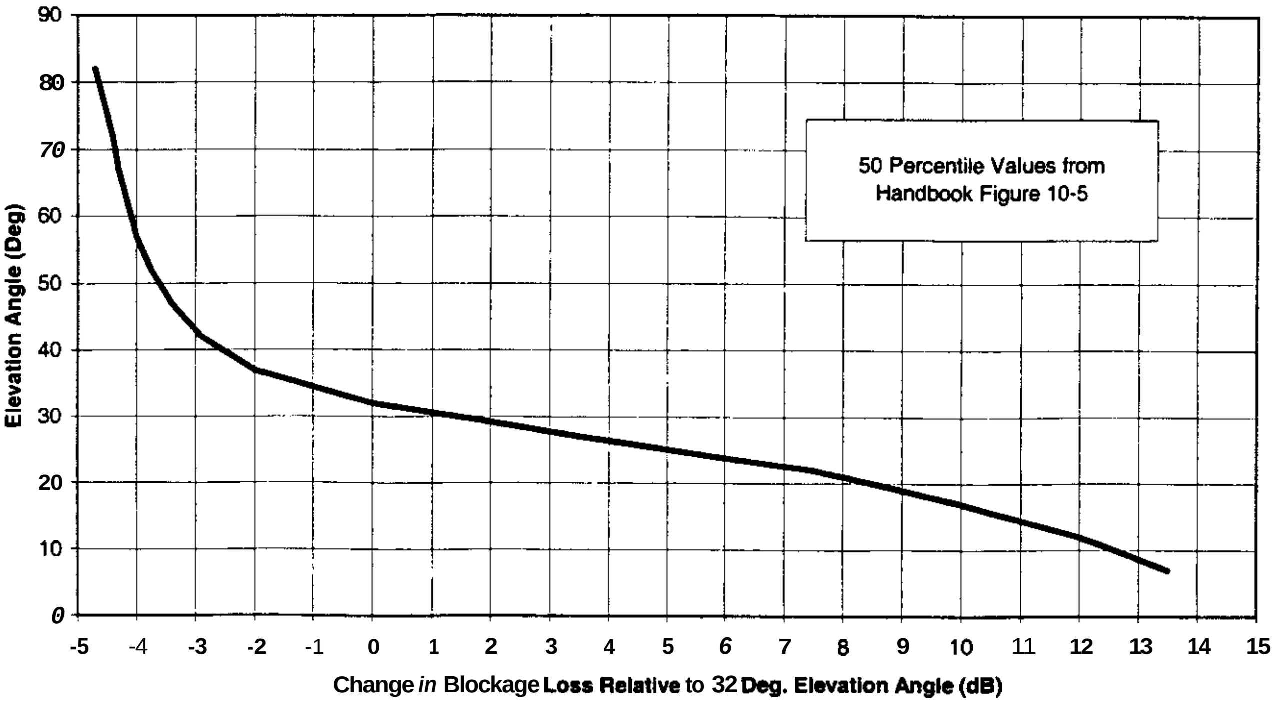
GSO Location	Inmarsat AOR-E 15.5 W.L.	Inmarsat AOR-W 54 W.L.	Inmarsat POR 142 W.L.	MSV 101 W.L.
Washington	14.0	40.7	11.2	40.2
Boston	16.3	38.1	5.3	32.5
Miami	14.3	48.4	16.9	52.2
Dallas	-	30.6	29.0	51.9
Denver		20.8	30.4	43.9
Bismarck	5.1	32.3		41.5
Seattle		7.4	37.2	36.7
San Francisco	-	8.5	41.9	41.2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

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.

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



1.23 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.

[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.

13.1 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.

13.2 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,

[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).*

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.

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.

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.

13.5 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

[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_CDI chaptr04/outage/linkbudg.htm.

[80] See Toftgaard *supra* note 65.

- 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?' 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[7‘] 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.

13.4 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 Tnftgaard *supra* note 65

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:

$$L=20Log_{10}(F)+20Log_{10}(D)+32.45;$$

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

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

[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).

	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

81 See ETSI Standard 300 609-1 and 300 609-4.

82 See 41 C.F.R. $24.238.

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

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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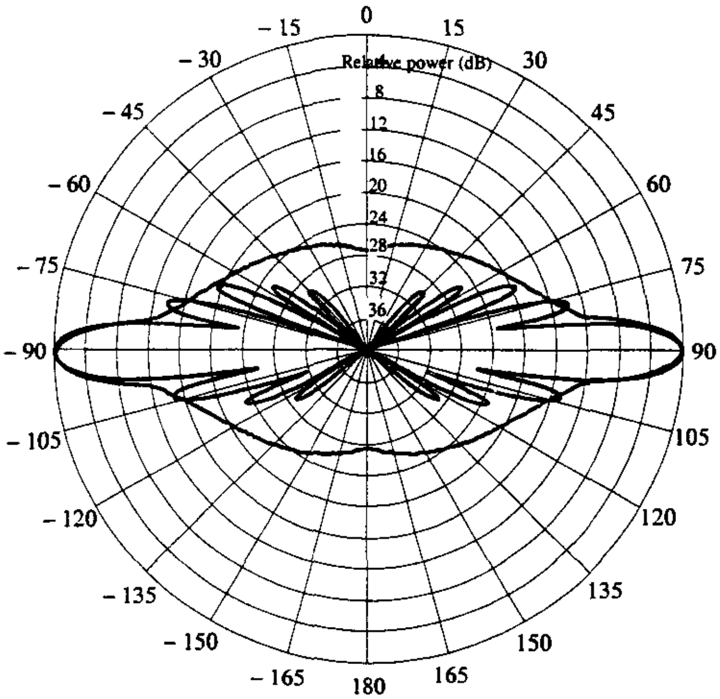
[86] Voice encoders are used to digitize the human voice for delivery over a digital communications system. The quality of the reproduced voice depends upon the algorithms used to encode and decode voice and the data rate of the resulting digital voice representation. The standard GSM vocoder data rate 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* Pane Letter at 3.

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 Omnidirecrional. Secroral and Other Antennas In Point-To-Multipoint Systems For Use In Sharing Studies In The Frequency Range From 1 GHz To Aboirr 70 GHz.***

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

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

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

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

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.

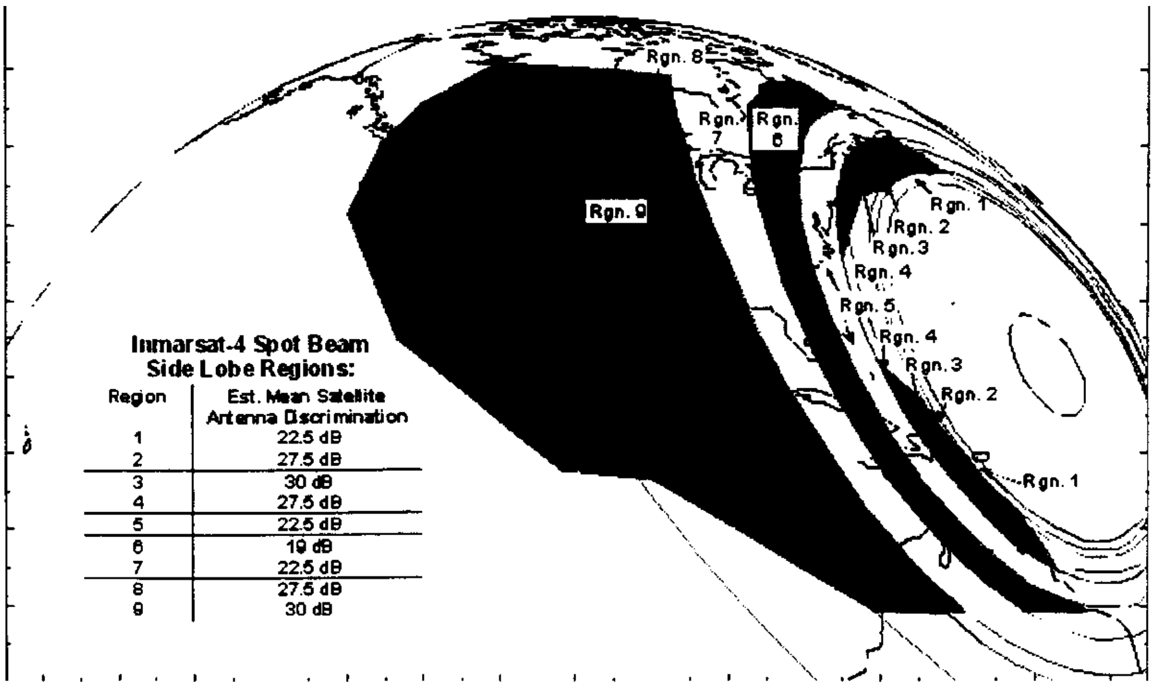
Table 1.10.A Vocoder Associated Transmit Power and Duty Cycles

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.

[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.

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



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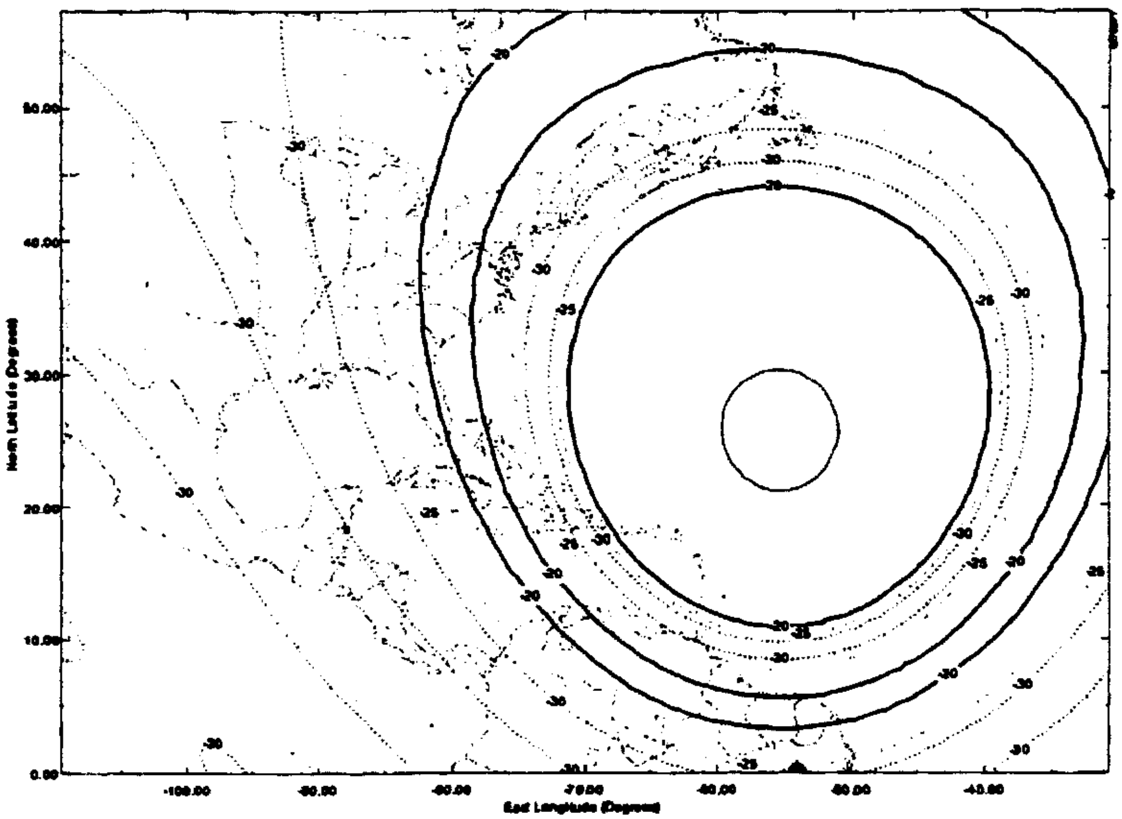
92 *See* Inmarsat Comments, Technical App., Table 3.3-2, dated October 22, 2001. The actual term that appears in the Table is -120 dBW, which is equivalent to -90 dBm.

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

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

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



[91] *See* MSV Nov. 4, 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.

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.% 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." 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 Pane 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.

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.

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

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 GK	(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	-19.5	-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 Facto	(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 Isolatior	(dB)	0.0	0.0	1.4	0.0	0.0	1.4
Received Power	(dBW/Hz)	-241.2	- 9.7	-293.7	-227.2	55.7	-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-TK	(%)	14.1	0.02	0.0004	382	0.54	0.11
Total delta-TK 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]

[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.

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.C - Comparison of Current Operations and Future MSS and ATC Terminal Usage on Inmarsst-3 and Inmarsat-4 for Adjacent Beam 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
MT EIRP	(dBW)	16	5	0		5	0
Bandwidth		6	50	200		50	200
MT EIRP Density	(dBW/Hz)	-21.8	-42.0	-53.0		-42.0	-53.0
Required OOB Reduction	(dBW/Hz)	0.0	0.0	0.0		0.0	0.0
Max OOB	(dBW/Hz)	-21.8	-42.0	-53.0		-42.0	-53.0
Relative Power Density	(dB)	0.0	-20.2	-31.2			
Inmarsat Gain	(dBi)	27	27	27		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
Outdoor Blockage	(dB)	0.0	0.0	3.1		0.0	3.1
Power Control	(dB)	0.0	2.0	20.0		2.0	20.0
Vocoder Factor	(dB)	0.0	0.0	3.5		0.0	3.5
Voice activity	(dB)	0.0	3.0	1.0		3.0	1.0
Polarization Isolation	(dB)	0.0	0.0	1.4		0.0	1.4
Received Power	(dBW/Hz)	-205.5	-230.7	-265.7		-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.I	0.00003		1.2	0.0004
Max # Co-freq Carriers	(#)	2	20	1725		20	1725
Total Delta T/T	(%)	58.61	1.8	0.05			

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.

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%

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 Porte 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 2.1.1D – 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%

[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.

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

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.

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

Parameter	Units	MSV MT	nmarsat 13 Case 1 In-band	Inmarsat I4 Case 1 In-band	Inmarsat I3 Case2 In-beam	Inmarsat I4 Case2 In-beam
Satellite Rec. Noise Temp.	(K)	45	700	650	700	650
Satellite Noise Density (No)	(dBW/Hz)	-202.				
Allowed Degradation	(dB)	0.2				
Allowed No+Io	(dBW/Hz)	-201.				
Allowed Interference Den. (Io)	(dBW/Hz)	-214.				
Effective MSV User Power	(dBW/Hz)		-57.0	-57.0		-57.0
Satellite Gain	(dBi)	41.	27.0	41.0		41.0
Relative Loss	(dB)	188.	188.7	188.7	188.7	188.7
Relative Sat Antenna Discrimination	(dB)	10.	22.0	25.0		0.0
Relative Spectrum Roll-Off	(dB)	0.	0.0	0.0	50.0	50.0
Effective MSV User Power	(dBW/Hz)	-57.				
Inmarsat Interference Per MSV Beam	(dBW/Hz)		-240.7	-229.7	268.7	-254.7
No. Inmarsat Beams per MSV Beam	(#)					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.	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

[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.

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 2211A Link Budgets Examining Possibility of Saturation of Inmarsat Mobile Earth Stations (MES) in Urban Areas

Parameter	Units	Inmarsat	MSV	Staff
		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	-15	-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

[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.

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'" 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.'" For non-urban environments free-space propagation is assumed.

[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.

Table 23.1.2.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	1.2
I/N	(dB)	37.91	-23.9	-11.41

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

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

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"' and Inmarsat proposes **a** 3 dB polarization factor."' **MSV** substantiated the **8** dB factor through both theory and measurement.

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

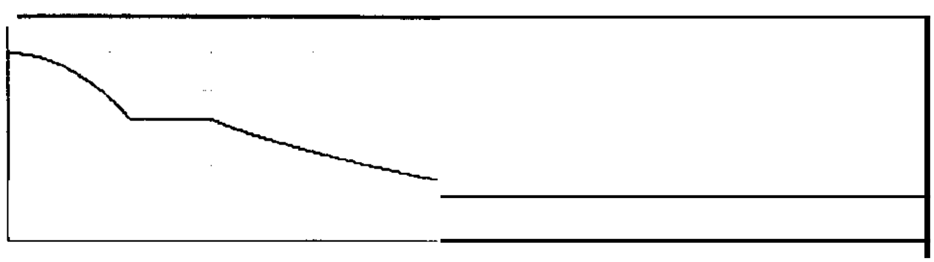
[116] Inmarsat Comments, Technical Annex, Table 3.4-1.

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

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

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	31.2
San Francisco, CA	8.5	41.9	41.9
San Diego, CA	14.0	43.7	43.7



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) outsf-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 EIRF' 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.

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

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 2.2.13.A Required Separation between Inmarsat Receiver and MSV Base Station (Free Space Propaga[illegible]on)

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

Parameter	Units	Value
- - -	(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.

[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).

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.

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

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.'"

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-toedge 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) Sewice (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	
EJRP density/carrier	(dBW/Hz)	-33.9	
Spurious EJRP 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. 101.6dB 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.